STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

# GEOLOGY OF MINERAL DEPOSITS IN THE UBEHEBE PEAK QUADRANGLE INYO COUNTY, CALIFORNIA

SPECIAL REPORT 42



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# GEOLOGY OF MINERAL DEPOSITS IN THE UBEHEBE PEAK QUADRANGLE INYO COUNTY, CALIFORNIA

By JAMES F. McALLISTER
Geological Survey, U. S. Department of the Interior

Price $2.00

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By James F. McAllister †

## OUTLINE OF REPORT



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† Geologist, U. S. Geological Survey.

### Illustrations

## ABSTRACT

The Ubehebe Peak quadrangle in Inyo County of eastern California contains the old Ubehebe mining district, which was first known for the scattered copper deposits and later for the deposits of silver, lead, gold, and most recently zinc. This 15-minute quadrangle (36° 30′ to 36°45′ N. and 117°30′ to 117°45′ W.) extending from the Inyo Range to the Panamint Range in the Owens Valley-Death Valley region is in the Basin and Range physiographic province. Although the rugged and dry country, isolated from transportation systems, makes the bulky nonmetallic deposits commercially unattractive and has impeded mining of the metallic mineral deposits, mines in the quadrangle produced during the period from 1908 to 1951, according to records of the U. S. Bureau of Mines, at least 4,788 tons of ore containing 334 ounces of gold, 44,729 ounces of silver, 120,180 pounds of copper, 2,657,559 pounds of lead, and (recorded since 1946) 165,959 pounds of zinc. The earliest production of gold (perhaps 2,000 to 4,000 ounces) and of copper does not appear in these records. The first discovery of ore deposits, which contained copper carbonate and silver, was sometime before 1875, when the Ubehebe mining district was established. After considerable activity on properties containing copper principally but some lead, silver, and gold, the first recorded production was of some silver from the Ubehebe mine during 1908. Soon thereafter lead, copper, and a little gold were produced. The maximum recorded annual production of lead and silver was 1,120,343 pounds of lead and 15,222 ounces of silver in ore from the Ubehebe mine in 1928; 82,000 pounds of copper in ore from the Anton and Pobst mine during 1916; 97 ounces of gold from the Lost Burro mine in 1935; and 53,854 pounds of zinc in ore from the Ubehebe mine in 1948. The Ubehebe mine has had the longest and most productive history in the area, but the Lippincott mine produced more continuously in the decade preceding 1952.

The metallic mineral deposits, as shown by their geologic setting in the Ubehebe Peak quadrangle, are mostly in Paleozoic rocks near intrusive contacts with Mesozoic plutonic rocks, but some are within the plutonic rocks near the contacts. The exposed Paleozoic rocks, which were originally marine sedimentary deposits, consist predominantly of limestone and dolomite but include quartzite, siltstone, shale, chert, and very little conglomerate. The sequence, which extends from Middle(?) Cambrian to Permian in a composite section more than 15,000 feet thick, has been regionally mapped in the following formations: Racetrack dolomite (Middle(?) Cambrian), Nopah formation (Upper Cambrian), Pogonip limestone (Lower Ordovician), Eureka quartzite (Middle Ordovician), Ely Springs dolomite (Upper Ordovician), Hidden Valley dolomite (Silurian into Lower Devonian), Lost Burro formation (Middle and Upper Devonian), Tin Mountain limestone (Mississippian), Perdido formation (Mississippian), Rest Spring shale (Pennsylvanian(?)), and Bird Spring(?) formation (Pennsylvanian and Permian). Each of these formations, except the Racetrack dolomite and the Nopah formation, appears on some map of a mine area, but the principal ore-bearing formations are the Ely Springs dolomite and the Lost Burro formation. A great gap in the sedimentary sequence separates the Permia rocks from late Pliocene(?) and younger continenta deposits. The Cenozoic rocks, which contain in thei older parts some olivine basalt, concern the metalli mineral deposits only to the extent that they may cove some mineralized zones.

The plutonic rocks, which have been correlated wit the complex of late Jurassic or early Cretaceous ag in the Inyo Range and the Sierra Nevada, in grea part consist of quartz-monzonite but include a wid range in variation (granite, granodiorite, syenite, mi nette, monzonite, syenodiorite, diorite, syenogabbro, an gabbro) along some contacts of the larger masses an in the small satellites. The kinds of plutonic rocks tha are different from quartz-monzonite, although of smal volume, are disproportionately common near the min eral deposits, because the distribution of mineral deposit and of varied rocks is closely related to the intrusiv contacts.

The calc-silicate rocks, which are the product of con tact metamorphism of Paleozoic limestones and dolo mites by the plutonic rocks, occur irregularly in marbl along intrusive contacts and predominantly in carbonat formations that are normally silty, shaly, or cherty. Th calc-silicate rocks consist principally of varied combina tions of garnet, diopside, idocrase, epidote, albite, ortho clase, wollastonite, tremolite, calcite, and quartz. A some places they contain scapolite, phlogopite, antigo rite, chrysotile, or magnetite. The calc-silicate rocks con tain most of the copper deposits and some of the area few known occurrences of tungsten minerals.

The regional structure consists of the following north-trending folds and some contemporaneous thrus faults in the Paleozoic rocks, a batholith and its sate lites of late(?) Mesozoic age, which transected and de formed some parts of the earlier folds and thrust faults a major angular unconformity across the Paleozoic an Mesozoic rocks and under the volcanic rocks and othe continental deposits of late Cenozoic age; and lat faults, some of which displaced the present topograph Ore deposits were localized along minor faults, sha tered zones, and possibly some favorable beds; the ore controlling fractures to a large extent were probabl caused by the disruptive force of intrusions.

The nonmetallic deposits, including capillary concen trations of ulexite in the bottom of Saline Valley, a litt talc, and poor showings of chrysotile asbestos, warra only the briefest description.

The metallic mineral deposits are in groups broadl spaced across the quadrangle, but the more producti ones are in the hills around Racetrack Valley. The o deposits are mostly in veins and in irregular replac ments along zones of fractured Paleozoic rocks near i trusive contacts. The best-defined veins, however, are the borders of plutonic rocks. Stratigraphy througho the area appears to have had little selective control ov mineral deposition except in the broad sense that fo mations of massive quartzite or thick shale were n favorable and that limestone and dolomite were the mo receptive. Characteristics of the hypogene deposit which probably range from pyrometasomatic to mes thermal, are largely obscured by supergene alteratio A great part of the mined deposits were oxidized pra tically in place.

The lead-zinc-silver ore deposits are in the Ely Springs lolomite at the Ubehebe mine, the Lost Burro formation t the Lippincott mine, marble (possibly of the Perdido ormation) at the Shirley Ann mine, and a border facies f quartz-monzonite at the Cerrusite mine. The hypogene re minerals in the ore deposits are silver-bearing galena nd sphalerite, associated with some pyrite and at some laces a little chalcopyrite or tetrahedrite. They are vell masked at most exposures by supergene minerals: erussite, traces of anglesite, locally abundant wulfenite nd arsenian vanadinite, hemimorphite, and some hydro-incite. Limonite is abundant in much of the supergene re, whereas malachite and chrysocolla are sparse. The re in general filled some small fractures and replaced hattered zones in dolomite marble interbedded at some laces with thin quartzite, locally perhaps favoring par-icular beds; but in the Cerrusite mine it formed an regular lode following a fractured zone in a sericitized order facies of quartz-monzonite. The outlines of mined re shoots are irregularly pod-shaped and plunge steeply, s in the Lippincott mine, or gently, as in the Ubehebe ine. The largest ore shoot, as outlined by the south stope the Ubehebe mine, is at most 110 feet long, 20 feet ide, and 12 feet thick. Nearly continuous pods of ore in ie main workings of the Lippincott mine constitute an lmost vertical pipelike ore zone that in 1951 had been ined down from the surface for about 250 feet.

The single noteworthy gold deposit, at the Lost Burro ine, was formed in a well-defined vein that extends into venodiorite from the contact with Tin Mountain lime-one. Traces of native gold remain in dull reddish brown isper that cuts across shattered quartz. A little chalco-yrite and pyrite occur in the quartz, and abundant monite is associated with the gangue of quartz, very arse grained calcite, and much clay. The vein, which in ie walls of the workings is commonly about 2 feet thick ut in stopes may have thickened to 8 feet, undulates atly and rolls into steep faults, none of which shift it ore than 30 feet. Ore shoots, as indicated by stopes, ccurred within a block about 350 feet long, 50 feet wide, nd at a difference in altitude of 75 feet.

The copper deposits are the most numerous and wide-read deposits in the quadrangle but are small. They ccur largely in contact-metamorphic calc-silicate rock roduced from most of the formations in the sequence etween the Nopah formation and the Bird Spring(?) rmation. A noteworthy exception, at the Copper ueen-Lucky Boy mine, occurs in a thick quartz-calcite ein within the border of a quartz-monzonite batholith. he conspicuous copper minerals in the deposits of the uadrangle are chrysocolla, malachite, and a little azu-te, but there is also some chalcopyrite, chalcocite, vellite, bornite, and cuprite. The associated metallic nstituents are mostly magnetite, limonite, and hema-te, but they include some pyrite, galena, and a little heelite, some of which is stained with cuprotungstite. he gangue consists of brownish and reddish jasper, ght-gray chalcedony, quartz, calcite, and other typical nstituents of calc-silicate rock.

The known occurrences of tungsten minerals are mited to one ferberite deposit and several occurrences scheelite at widely separated localities. Ferberite at ie Monarch mine occurs in quartz-calcite veinlets in uartz-monzonite. The scheelite commonly occurs in tactite that contains some copper minerals, but a few grains of scheelite occur also in light-colored contact-metamorphic rocks and a syenite pegmatite. The coarsest-grained scheelite (as much as 2 inches long, on the Cuprotungstite claim), which contains some cuprotung-stite, is in a mass of copper- and iron-mineralized tactite a few feet in diameter in dolomite marble of the Pogonip limestone, about 500 feet from the exposed contact of a quartz-monzonite batholith. An ultraviolet lamp failed to show any scheelite in the Ubehebe, Lippincott, or Lost Burro mines. Extensive zones of tactite throughout the quadrangle are perhaps inadequately prospected for scheelite.

Detailed descriptions of the mine areas, particularly the Ubehebe, Lippincott, Lost Burro, Sally Ann, Cerru-site, and Shirley Ann areas, and an annotated list of about 75 minerals that occur in the quadrangle are major parts of the report.

## INTRODUCTION

The Ubehebe Peak 15-minute quadrangle lies in the northeastern fringe of a well-mineralized belt that ex-tends diagonally southeastward from Bishop to Tecopa in Inyo County (see fig. 1). The mineral deposits in this quadrangle, although they are much smaller than many of the better-known deposits in the belt, provide a good opportunity to observe relationships to a varied geologic setting. The quadrangle, which lies between 36°30′ and 36°45′ N. and between 117°30′ and 117°45′ W., is 30 miles east of Mount Whitney and about 20 miles west of the middle of northern Death Valley. It extends from the eastern flank of the Inyo Range to the western flank of the Panamint Range and across the Nelson Range, which connects the ranges and separates Saline Valley from the northern end of Panamint Valley.

Physiographically the quadrangle is in the south-western part of the Great Basin in the Basin and Range province. Drainage flows into five closed basins: about 68 percent of the quadrangle drains into Saline Valley, 15 percent into Panamint Valley, 13 percent into Race-track Valley, 4 percent into the closed part of Hidden Valley, and less than 1 percent drains from the extreme southwestern corner into Owens Valley.*

The divides between the basins interconnect in sinuous complexity, but the whole expression of the topography within the quadrangle emphasizes a convergence of the mountains southward and southeastward to Hunter Mountain of the Panamint Range. The greatest local re-lief is 5,500 feet on the northern slope of the Nelson Range, where a peak 7,701 feet above sea level is the highest point in the quadrangle. In Saline Valley, about 12 miles from the highest point, is the lowest point, about 1,075 feet above sea level. The relief around the mineral deposits is rarely more than 1,000 to 2,000 feet, and the altitudes of the deposits range from 2,600 to 6,800 feet above sea level. The altitude of a mineral de-posit, as in other parts of the Inyo-Panamint region, largely determines the extent to which seasonal extremes in temperature discourage prospecting and mining. Be-low 3,000 feet summer temperatures are disagreeably hot and above 6,000 feet winter temperatures often are unpleasantly cold; strong winds in any season accent the extremes in temperature.

* Topographic map of the Ubehebe Peak quadrangle, U. S. Geological Survey, 1951.

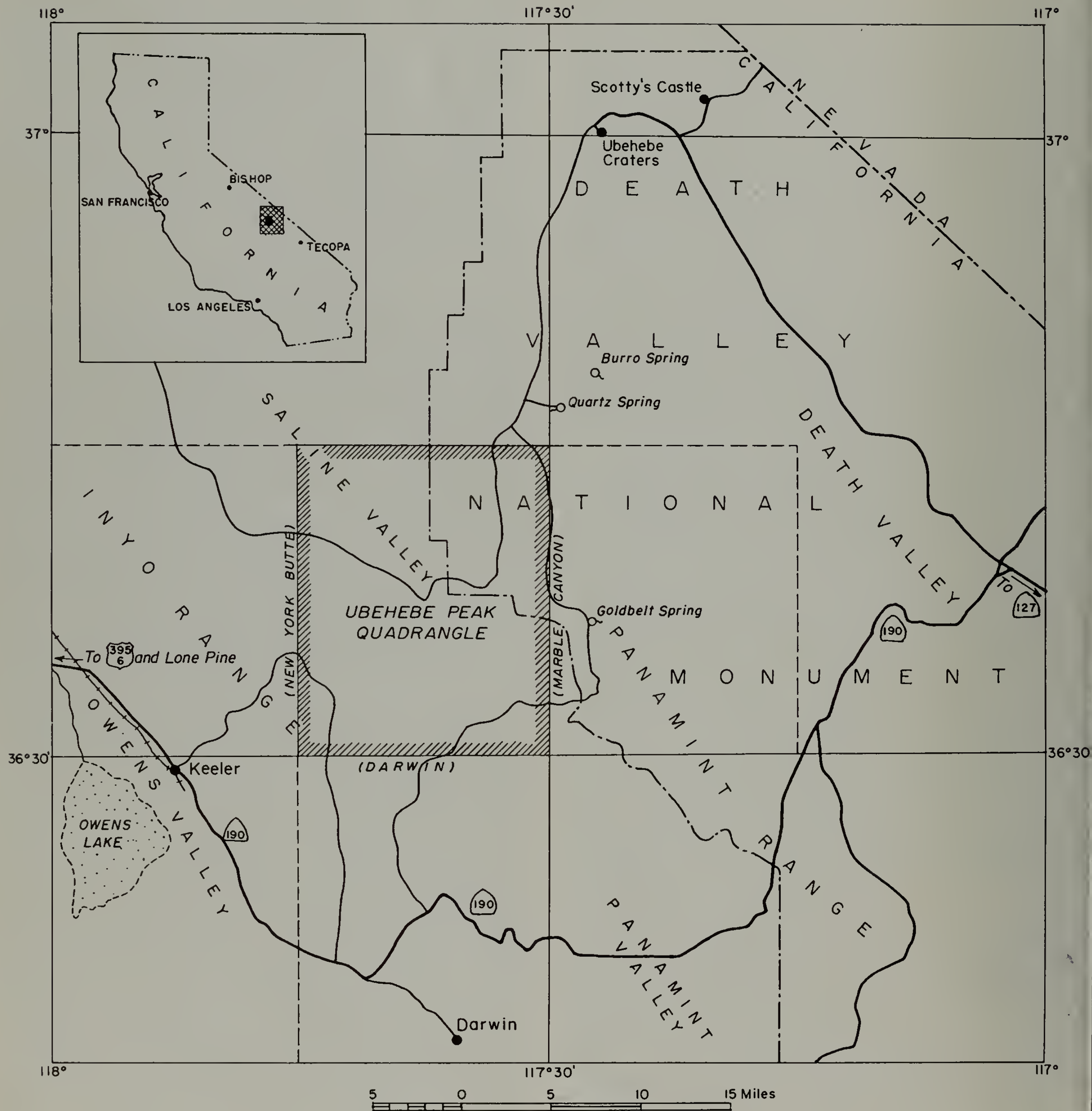


FIGURE 1. Map showing location of the Ubehebe Peak quadrangle.

The precipitation is nowhere plentiful and in most of the quadrangle it is slight and sporadic. Cloudbursts occasionally wash out some parts of the roads. Noticeable local differences in total precipitation are controlled in a general way by the altitude of the land. There are no perennial springs and seeps except at a few places on Hunter Mountain and around its western and southwestern periphery. All the mine workings are dry. The springs are inaccessible or far from most of the mineral deposits. Recent miners therefore have brought in all their water, sometimes from Goldbelt Spring, which is accessible by a circuitous road through Hidden Valley, occasionally from the limited supply at Quartz Spring, which is about 5½ miles by road from the northern border of the quadrangle, and more frequently from Scotty's Castle, which is beyond Death Valley and 30 miles from the quadrangle. Lack of water near the mineral deposits thus is a major difficulty in mining.

The amount of precipitation and its retention are roughly expressed by the irregular effect on the vertical zoning of vegetation, from pinyon and juniper woodland (fig. 7) in some of the highest country, lower through sagebrush desert, to creosote-bush desert (fig. 5) and nearly bare slopes (fig. 6). Pinyons and junipers grow commonly at altitudes above 6,400 feet, but on favorably located shaded slopes they extend more than 1,000 feet lower, marking places where snow remains longest after winter storms. The pinyon-juniper open woodlands thin at lower altitudes to scattered junipers and to good stands of Joshua trees (fig. 18) on some gentle slopes of alluvium between 5,000 and 6,000 feet above sea level. The largest woodlands are on top of Hunter Mountain and around the mountain in the southwestern corner of the quadrangle. At best the trees are a source of firewood and crude timbers for small mines, and they are restricted to the southern quarter of the Ubehebe Peak quadrangle. This part contains, in the Nelson Range, only one small group of the mineral deposits. The lack of wood for fuel and timbering was a detriment to mining in the early days but now has little effect.

At present, two of the major hindrances to mining activity are the isolation of the mineral deposits from settlements and the difficulty of constructing and maintaining roads to established systems of transportation. Within the 240 square miles of the quadrangle there are no settlements and only one cattle ranch, which is in the extreme southern part and not permanently inhabited. The nearest town, other than Darwin, is Keeler, which is on a narrow-gauge branch of the Southern Pacific Railroad and on California Highway 190, about 32 miles by road from the southern edge of the quadrangle. Although a rough road crosses from the southern edge, through Saline Valley, to the mines in the northeastern quadrant, common access to the mines has been by a paved road through Death Valley to the Ubehebe Craters at the northern end and then southward 21 miles on an unpaved road through Racetrack Valley (fig. 1).

Little information about the geology of the area has been published. The earliest known published map (Spurr, 1903, pl. 1) that distinguishes kinds of rock in the region has patterns for Pleistocene stratified rock and Tertiary volcanic rock covering the entire area of the present Ubehebe Peak quadrangle, which is but a minute portion of this early reconnaissance map of southern Nevada and a large adjacent part of California. Additional rocks are distinguished in the first published geologic map of Inyo County (Waring, 1917), which roughly outlines the Paleozoic sedimentary rocks, the granitic rocks intruded into them, Tertiary volcanic rocks, and the alluvium. The distribution of even these large groups of rocks is of some significance to those concerned with the occurrence of the mineral deposits. The latest compilation for the geologic map of California (Jenkins, 1938, Sheet V), however, relying on an unpublished source rather than on Waring's map of Inyo County, does not show the principal masses of intrusive rock, the overlapping volcanic rock, nor a large part of the alluvium. Other published reconnaissance maps end at the eastern and western boundaries of the quadrangle (Ball, 1907, pl. 1; Knopf, 1918, pl. II) or well south of the quadrangle (Hopper, 1947, pl. 1). An unpublished map of the New York Butte quadrangle (Merriam and Smith, in preparation), which adjoins the western boundary of the Ubehebe Peak quadrangle, and an unpublished map of the part of the Darwin quadrangle (Hall and MacKevett, in preparation) that adjoins the southern boundary of the Ubehebe Peak quadrangle, deal with some of the same formations and structure. Brief descriptions of many of the mines and prospects located in the Ubehebe Peak quadrangle have appeared in reports on the mines and mineral resources of Inyo County (for bibliography see Norman and Stewart, 1951, pp. 132-136).

Field work on the geology and mineral deposits of the Ubehebe Peak quadrangle was undertaken by the U. S. Geological Survey in cooperation with the California Division of Mines, from the autumn of 1946 intermittently until 1951. Mine areas and workings were mapped in conjunction with geologic mapping of the quadrangle, which clarified the stratigraphic and structural setting of the mineral deposits. The sequence and validity of the Paleozoic formations as mappable units of rock were previously established by the writer in the adjacent and slightly overlapping Quartz Spring area, where most of the field work was done independently by the writer in 1938, but was started in 1937 under the supervision of H. D. Curry and the auspices of the National Park Service. Results of the two periods of field work in the adjacent areas have been closely integrated. A report on the Quartz Spring area (McAllister, 1952), describes in detail most of the Paleozoic stratigraphy that is applicable to the geology of the Ubehebe Peak quadrangle. A geologic map, structure sections, and brief text concerning the geology of the quadrangle are being prepared for publication by the U. S. Geological Survey. The present report describes in considerable detail the mineral deposits and some other occurrences of minerals in the geologic setting of the Ubehebe Peak quadrangle.

Base maps for the geology of the mine areas and workings were surveyed several different ways. The simplest surface map (Shirley Ann area, fig. 21), without contour lines, was plotted from measurements made with a tape, Brunton compass, and clinometer. Some topographic maps (Ubehebe, pl. 1; Lost Burro, pl. 3; Cerrusite, fig. 19) were made with a telescopic alidade and plane table along stadia traverses, and more accurate ones (Lippin-

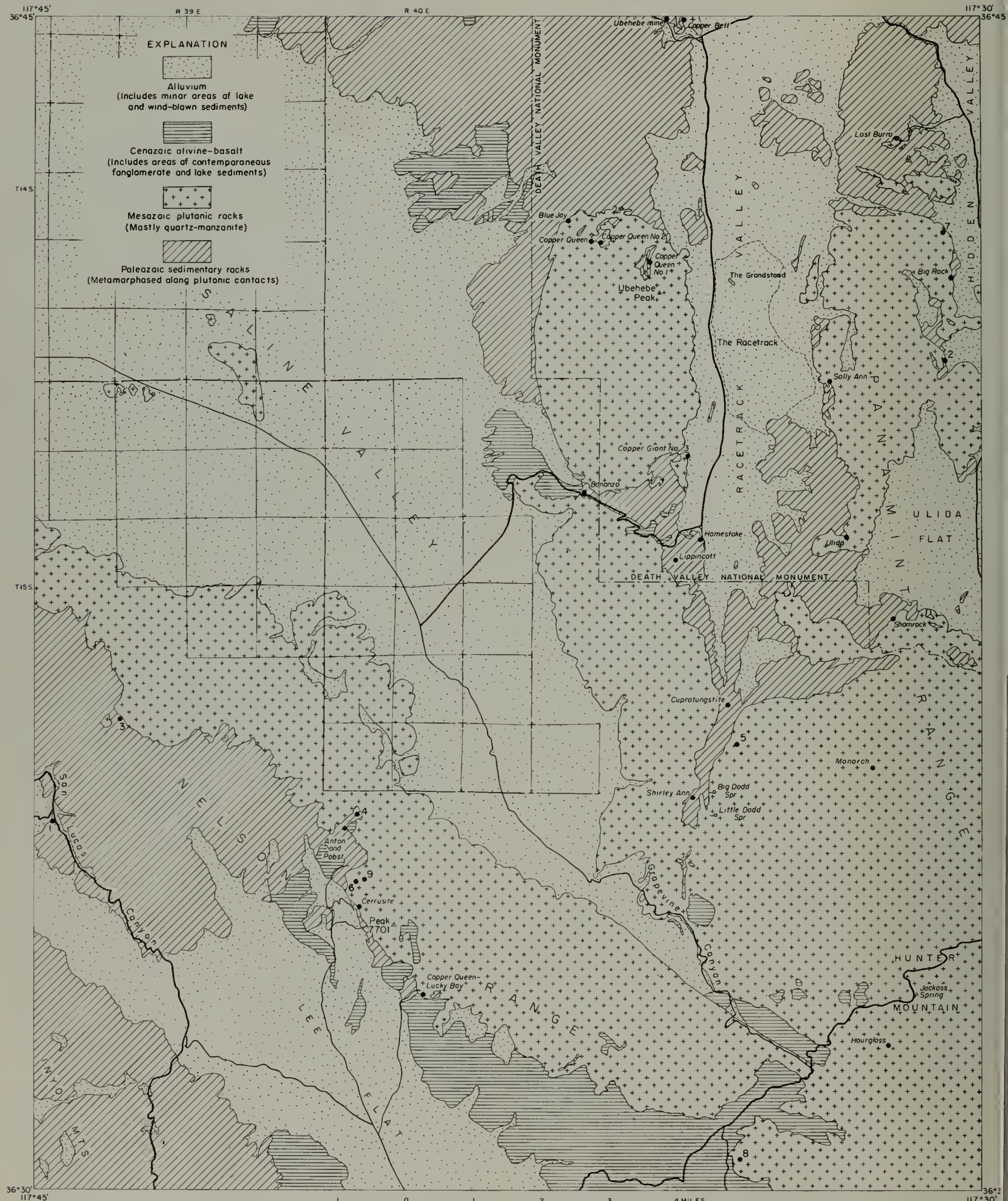


FIGURE 2. Simplified map of the Ubehebe Peak quadrangle, showing location of principal topographic features and generalized litholog setting of mines, some prospects, and numbered mineral localities.

| | Age | Formation name and approximate thickness | Lithology |
|---|---|---|---|
| CENOZOIC | QUATERNARY AND LATE TERTIARY (?) | | Alluvium; lake and wind-blown sediments. |
| | | | Angular unconformity |
| | | | Old fanglomerate; some lake sediments; some pyroclastic basalt; in general under basalt flows. |
| | | | Unconformity |
| MESOZOIC | CRETACEOUS (?) | | Quartz-monzonite and associated plutonic rocks. |
| | | | Intrusive contact |
| PALEOZOIC | PERMIAN | Bird Spring (?) formation 5,000+ feet | Limestone conglomerate; shale, limestone; sandy and pebbly limestone. Intraformational unconformities. |
| | CARBONIFEROUS | Rest Spring shale 310+ feet | Olive-gray shale and siltstone. |
| | | Perdido formation 610± feet | Brownish-weathering siltstone; dark-gray limestone and chert; some conglomerate and shale. Possible intraformational disconformity. |
| | | Tin Mountain limestone 475 feet | Conspicuously dark gray limestone, shaly in lower part; some chert in nodules and lenses. |
| | DEVONIAN | Lost Burro formation 1,525 feet Lippincott member✡ | Light- and dark-gray dolomite and limestone; thin sandstones at top and bottom. Sandy or quartzitic basal unit. |
| | SILURIAN | Hidden Valley dolomite 1,365 feet | Medium-gray and very light gray dolomite; abundant nodular chert in lowest part. |
| | ORDOVICIAN | Ely Springs dolomite 940 feet | Light-gray dolomite in upper part; lower part, conspicuously dark gray dolomite, cherty. |
| | | Eureka quartzite 400 feet | Upper part, massive vitreous nearly white quartzite; lower part, ferruginous and somewhat shaly quartzite. |
| | | Pogonip limestone 1,440 feet | Dolomite and limestone; some shale, chert, and sandy or quartzitic beds. |
| | CAMBRIAN | Nopah limestone 1,600 feet | Light- and dark-gray dolomite; shaly limestone in basal unit. |
| | | Racetrack dolomite 1,900± feet | Light- to dark-gray dolomite; some chert and very little shale in lower part. |

✡ New name

FIGURE 3. Stratigraphic sequence in the Ubehebe Peak quadrangle.

cott, pl. 2; Sally Ann, fig. 25) were made by planetabling a triangulation network. The initial altitude of each map area, determined by aneroid, was adjusted approximately to the altitude of the same point on the subsequent topographic map of the Ubehebe Peak quadrangle. Mine workings were mapped by means of a tape, Brunton compass, and clinometer, except in the Lost Burro mine, where a Brunton-attachment alidade was used on a light plane table. All the maps were oriented by compass, using a declination of about 16½°E.

It is a pleasure to acknowledge the cooperation of mine property owners and operators, particularly Grant Snyder, W. C. Thompson, and George Lippincott. Assistance in mapping is acknowledged in the description of mine areas. The work was benefited by brief visits in the field with several members of the U. S. Geological Survey, especially Ward Smith, C. W. Merriam, A. R. Kinkel, Jr., and Q. D. Singewald, and with O. P. Jenkins and L. A. Norman, Jr., of the California Division of Mines.

## GEOLOGIC SETTING OF THE MINERAL DEPOSITS

The mineral deposits have yielded commercial quantities of lead, zinc, silver, gold, copper, and allegedly some tungsten but no nonmetallic commodity other than, perhaps, borax. Minor occurrences of talc and chrysotile asbestos are known, but they are not exploitable. The metalliferous deposits generally occur in the Paleozoic sedimentary rocks that range from Ordovician to Permian, near intrusive contacts of Mesozoic quartz-monzonite (fig. 3); but a few occur within the intrusive masses. These pre-Cenozoic rocks are exposed in about half of the area of the quadrangle (fig. 2). The other half of the area is covered with Quaternary and some possibly Upper Tertiary gravel, remnants of basalt flows, some lake sediments, and local veneers of wind-blown sediments. The Paleozoic rocks are folded, faulted, and at some places intensely deformed by intrusions, but only the most minor elements of structure, such as short faults and shattered zones, localized the metalliferous mineral deposits.

### Sedimentary Rocks of Paleozoic Age

Rocks representing all the systems of the Paleozoic in a sequence from Middle(?) Cambrian to possibly middle Permian were originally marine sediments. They consist predominantly of limestone and dolomite, much smaller proportions of quartzite, siltstone, shale, and chert, and a very little conglomerate. Volcanic rocks are notably lacking in this sequence, although some shale in the Mississippian may be tuffaceous. The older rocks, from Cambrian to early Mississippian, are similar dolomites and limestones for the most part, but they contain widely spaced quartzite layers, sandy zones, and a few shaly zones, sufficiently distinctive to permit dividing the sequence into formations. The younger rocks are more heterogeneous: shale and siltstone are interbedded with limestone, much of which is silty, sandy, or even pebbly, and the sequence is capped with a coarse conglomerate of limestone. A composite section of the exposed rocks of the Paleozoic is more than 15,000 feet thick.

Formations in the local stratigraphic column of Paleozoic rocks, except the uppermost formation of Pennsylvanian and Permian age, were previously described in a report on the nearby Quartz Spring area (McAllister, 1952, pp. 8-27). Formation names well known in other parts of the Death Valley region and the Great Basin were used when possible, but it was necessary to introduce some new formations. The report on the Quartz Spring area contains considerably more stratigraphic information—details of lithology and thickness of units within the formations, lists of fossils and notes on their stratigraphic significance, and comments on correlation—than is necessary for the geologic setting of the mineral deposits in the Ubehebe Peak quadrangle. The following condensed descriptions of the formations are supplemented in the descriptions of mine areas by whatever stratigraphic details are pertinent to each area.

Around the mineral deposits metamorphism and structural deformation obscured many normal characteristics of the formations, but the identification of the formations has been substantiated by regional mapping. The stratigraphy appears to have had little selective control over mineral deposition except in the broadest sense that formations of massive quartzite or thick shale were not favorable and that limestone and dolomite were the most receptive rocks.

### Racetrack Dolomite

The oldest formation exposed is the Racetrack dolomite, which was described as a new formation in the Quartz Spring area (McAllister, 1952, pp. 8-9). Although no fossils have been found in the Racetrack dolomite, it is probably Middle Cambrian; it extends about 1,900 feet stratigraphically downward from the basal unit of the Nopah formation which contains Late Cambrian fossils. The only occurrence of the Racetrack dolomite within the quadrangle is in the foothills south of The Racetrack playa, where it contains no mineral deposits. The conspicuously predominant rock in the formation is gray dolomite in layers of different shades from nearly black to grayish yellow, but it contains varied quantities of nodular chert and, below the part exposed south of The Racetrack playa, some shaly dolomite. Many small bundles of tremolite in the dolomite show that the formation near The Racetrack playa is incipiently metamorphosed.

### Nopah Formation

Overlying the Racetrack dolomite, a gray dolomite was mapped here as the Nopah formation because it is equivalent in general lithology and stratigraphic position to the Nopah formation as originally described in the Nopah Range near the eastern boundary of California (Hazzard, 1937, pp. 320-321). A continuous section of the Nopah formation between the underlying Racetrack dolomite and the overlying Pogonip limestone in the Last Chance foothills, north of the Ubehebe Peak quadrangle, is about 1,600 feet thick. Diagnostic fossils in the lowermost beds and others in the upper third of the formation clearly place a large part of the Nopah formation in the Upper Cambrian (Bridge and Palmer *in* McAllister, 1952, p. 10). Dolomite in layers of varied gray and grayish yellow makes up most of the formation. Some of the dolomite contains irregularly distributed chert nodules. The main variation in lithology consists of brownish-weathering shaly and cherty limestone in a 250-foot basal zone, which makes a distinctive lower boundary of the formation. The Nopah formation crops out about a mile east of the Lippincott mine area. It is near an intrusive contact and is somewhat metamorphosed but contains none of the mineral deposits.

### Pogonip Limestone

A greater variety of rocks lying next above the Nopah formation constitutes the Pogonip limestone, which is a term long used for approximately equivalent rocks in central Nevada and more recently in the Nopah region of California (Hazzard, 1937, pp. 322-324). The Pogonip limestone, where measured in the Quartz Spring area, is about 1,400 feet thick. Dolomite and limestone, some of which are sandy or cherty, are the predominant rocks. They are, in general, lighter grays than the underlying dolomites in the Nopah formation, and they weather to tinges of yellow in the grays. The middle part of the formation contains some light-brown shale, some shaly limestone, and much siliceous limestone that weathers to a conspicuous brown and distinguishes the formation even at a considerable distance. The brown-weathering siliceous limestone has a crepe structure that is diagnostic. In the upper part of the Pogonip limestone, coils of large gastropods are persistent enough to be called a

FIGURE 4. Middle Paleozoic formations exposed on eastern slope of mountains north of Ubehebe Peak, from Racetrack Valley. Pogonip limestone, cropping out along base, is overlain by Eureka quartzite, Ely Springs dolomite, Hidden Valley dolomite, and Lost Burro formation along left skyline.

distinctive lithologic feature. At some places the upper part is sandy or quartzitic. Characteristic Pogonip fossils (Bridge and Copper *in* McAllister, 1952, p. 11) in shaly limestone near the middle and in dolomite and limestone near the top place the formation in the Lower Ordovician, or according to some usage, in the Lower and Middle Ordovician.

The Pogonip limestone crops out continuously for 1½ miles southward from the Ubehebe mine area, sporadically at other places around Racetrack Valley, and between Racetrack Valley and Big Dodd Spring. It contains the copper deposits at the Copper Bell mine and the coarse-grained scheelite associated with copper and iron minerals in the Cuprotungstite (Alvord ?) claim. Quartzitic parts of dolomite at the top of the formation contain some steatite grade of talc at other places in the region and should be examined carefully during further prospecting for talc.

#### Eureka Quartzite

The Eureka quartzite is perhaps the most easily recognizable formation in the region, and it is a particularly useful marker in the thick sequence of Paleozoic dolomite and limestone, especially in metamorphic zones where some other formations lost their distinctive characteristics. The formation was established in central Nevada and has been accepted without serious questioning for the equivalent rocks in eastern California. Although no fossils have been found in it here, Early Ordovician fossils that occur in the underlying Pogonip limestone and Late Ordovician fossils in the overlying Ely Springs dolomite confine the age of the Eureka quartzite to well within the Ordovician. The age by correlation is Middle Ordovician.

The Eureka quartzite, as seen in a continuous section about 2½ miles north of Ubehebe Peak (fig. 4), is 400 feet thick and consists of a lower unit of platy iron-bearing quartzite interstratified with some shale, and an upper unit of massive vitreous quartzite. The massive upper part is nearly white, weathering to pale tints, whereas the lower part is much darker, weathering brown. This combination distinguishes it from other quartzites in the region, wherever it may be by structure or exposure isolated from the normal stratigraphic succession. The Eureka quartzite occurs near some of the mineral deposits, as in the Ubehebe mine area (see pl. 1), and has been extensively prospected, but it contains none of the mineral deposits.

#### Ely Springs Dolomite

The predominantly dark gray Ely Springs dolomite contrasts sharply with the underlying Eureka quartzite (fig. 4). Use of the formation name has been extended from the original locality near Pioche in Nevada, through the Nopah-Resting Springs area, to the Ubehebe Peak region, where the formation is about 940 feet thick. The correlation by lithology and stratigraphic position is supported by some Late Ordovician fossils (Cooper *in* McAllister, 1952, p. 15).

Dark-gray dolomite, which contains many chert nodules, grades upward through medium-gray dolomite to light-gray dolomite. The lightest-gray part is much thinner than the darker part, but the actual proportions are somewhat different from place to place. The change from dark to light gray aids in distinguishing the Ely Springs dolomite from the overlying medium-gray basal part of the Hidden Valley dolomite.

The Ely Springs dolomite crops out from the Ubehebe mine to within half a mile of the intrusive contact north of Ubehebe Peak, from the contact south of the peak to alluvium in the Lippincott mine area, and along the western foot of a strike ridge at the southern end of Racetrack Valley. It contains the lead-zinc-silver deposits of the Ubehebe mine (pl. 1), which is the largest mine in the district, and it was altered to some talc on the Homestake claim.

#### Hidden Valley Dolomite

The Hidden Valley dolomite, which was originally described for the Quartz Spring area (McAllister, 1952, pp. 15-18), lies stratigraphically on the Ely Springs dolomite and is about 1,365 feet thick. The Hidden Valley dolomite consists of cherty medium-gray dolomite in the lower part, very light gray (nearly white) coarser-grained dolomite in the middle part, and medium-gray dolomite, which tends to weather light olive gray, in the upper part. The thickness of each unit is not uniform, but the thickness of the nearly white middle part is roughly equal to the others combined. The cherty and darker lowest unit somewhat resembles the dark cherty part of the Ely Springs dolomite, but this unit of the Hidden Valley dolomite is distinguished by the lighter gray color weathering olive gray and the relatively abundant Silurian fossils, as well as by its position above the lighter upper unit of the Ely Springs dolomite. Within the uppermost 65 feet of the Hidden Valley dolomite, the fossils are diagnostically Early Devonian in age (Cooper *in* McAllister, 1952, p. 17), but the formation in general is considered to be Silurian in age.

The Hidden Valley dolomite crops out continuously from the quadrangle's northern boundary west of the Ubehebe mine area southward to the intrusive contact north of Ubehebe Peak and from the southwestern contact of the same intrusive mass southeastward through the Lippincott mine area. Although it thus occurs near the two main lead-zinc-silver deposits, unquestionably Hidden Valley dolomite contains none of the mineral deposits of the quadrangle.

#### Lost Burro Formation

In the northeastern quarter of the quadrangle, the Lost Burro formation crops out more extensively than any other Paleozoic formation. It contains the lead-zinc-silver deposits of the Lippincott area and a majority of the copper deposits, such as on the Ulida, Sally Ann, and Blue Jay properties.

The Lost Burro formation at the type locality in Lost Burro Gap is 1,525 feet thick and consists mostly of interbedded dolomite and limestone. Light-gray layers alternate with dark-gray layers, making conspicuously striped mountainsides. Some of the dark layers regionally contain characteristic white spaghetti-shaped mottling and dark concentric cellular masses of Stromatoporas, which help to identify the formation. The lowermost and uppermost parts of the Lost Burro formation are marked by brown-weathering irregular sandy or quartzitic zones. The lower zone is thicker and more persistent than the upper one. The age of the Lost Burro formation is Late and probably Middle Devonian. Late

Devonian fossils occur in the topmost beds, and Early Devonian fossils occur 15 to 65 feet below the base, in the Hidden Valley dolomite. (Cooper *in* McAllister, 1952, pp. 17, 19.)

The basal siliceous zone, which is sporadically cherty and consistently sandy or quartzitic, is here designated the Lippincott member of the Lost Burro formation for the exposures northeast of all the workings of the Lippincott mine. The member where mapped in the Lippincott mine area (pl. 2) is a prominent rock unit, closely associated with lead deposits. Like most of the other rocks in the mine area, the Lippincott member here is somewhat metamorphosed.

The best exposure of the Lippincott member where the rock is not metamorphosed is in the Andy Hills east of Hidden Valley about 7 miles northeast of the Lippincott mine. Here it is 250 feet thick in a continuous stratigraphic sequence from Hidden Valley dolomite into the Lost Burro formation. The stratigraphic section in some detail follows (McAllister, 1952, p. 19):

| | Feet |
|---|---|
| Lost Burro formation: | |
| . . . | |
| Coarse-grained light-gray dolomite interbedded upward with darker-gray dolomite. | |
| Lippincott member: | |
| Medium-gray dolomite, more or less sandy, in lenses and poorly defined discontinuous beds; a few inconspicuous pebbles of light-gray dolomite in some of the sandy beds | 55 |
| Very light gray sandstone in massive layer; a little dolomite cement | 20 |
| Light-gray mudstone (nonfissile shale) | 15 |
| Gray chert, weathering brownish black, in medium light gray dolomite; less chert in sandier base | 35 |
| Medium-gray dolomite containing brownish-weathering sand and silt in poorly defined lenses and beds, and outlining conspicuous sinuous branching forms | 125 |
| | 250 |
| Hidden Valley dolomite: | |
| Medium dark gray dolomite, weathering light olive gray; Early Devonian fossils in lower 50 feet (*Spirifer kobehana* zone of Oriskany age) | 65 |
| . . . | |

At the type locality of the Lost Burro formation, 8 miles north-northeast of the mine, the sandy Lippincott member is only 155 feet thick; as in the Andy Hills, the 30-foot sandiest part starts 55 feet below the top of the member, and there is some chert in the underlying sandy dolomite. Much more extensive exposures of the member occur along the eastern flank of the mountains north of Ubehebe Peak, from 5 to 8 miles north of the mine. Where measured one place here it is 200 feet thick; it contains a 40-foot zone of quartzite 40 feet below the top of the sandy dolomite, and it has some chert in the underlying sandy dolomite. A few feet below the base there are some fossils from the Lower Devonian *Spirifer kobehana* zone. The exposures stop at the Ubehebe Peak stock of quartz-monzonite, near which the Lippincott member was metamorphosed to quartzite and quartzitic dolomite to the same extent as in the Lippincott area.

#### Tin Mountain Limestone

The dark Tin Mountain limestone, which is 475 feet thick at the type locality in the Quartz Spring area, consists of two parts: a lower unit of thin limestone beds interstratified with light brownish gray to pale red calcareous shale, and an upper, cliff-forming unit of dark limestone, which has some pale-red shaly partings. Chert

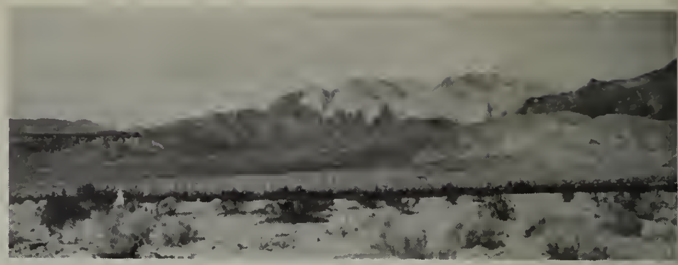

Figure 5. Upper Paleozoic formations exposed on western slope of mountains north of Ubehebe Peak, from Saline Valley. Steeply dipping Tin Mountain limestone in the middle makes conspicuously dark cliffs against lighter, underlying Lost Burro formation. Bird Spring(?) formation in middle left lies above Rest Spring shale and Perdido formation, which are indistinguishable in the photograph. In middle right the Bird Spring(?) formation is partly bleached from metamorphism by quartz-monzonite, which in right background is exposed in the Ubehebe Peak stock.

nodules are larger and more noticeable in the upper unit. Dark outcrops of the Tin Mountain limestone remain conspicuous at a distance, as in the cliffs several miles northwest of Ubehebe Peak (fig. 5) and on the mountain south of Lost Burro Gap. The fossiliferous Tin Mountain limestone is probably Mississippian in age (Williams and Duncan *in* McAllister, 1952, p. 21); it lies stratigraphically between those beds in the top of the Lost Burro formation containing Late Devonian fossils and beds in the bottom of the Perdido formation containing early Mississippian fossils. The formation occurs widely in the eastern half of the quadrangle and in small outcrops in the southwestern quarter, where it is the oldest exposed Paleozoic formation. The Tin Mountain limestone contains none of the mineral deposits, except possibly in the Dodd Springs area where some of the small copper occurrences may be in Tin Mountain limestone undifferentiated from other metamorphosed Paleozoic rocks. The Tin Mountain limestone is at the contact of the syenodiorite mass that contains the Lost Burro gold deposits, and 4 miles south of the quadrangle the limestone contains most of the lead-silver deposits at the Lee mine (MacKevett, written communication, 1951).

#### Perdido Formation

Lithologically transitional from the underlying Tin Mountain limestone to the overlying Rest Spring shale, the Perdido formation consists of limestone interbedded with shale, chert, calcareous siltstone, fine-grained sandstone, sandy limestone, and a little conglomerate. The lithologic diversity, variable from place to place, itself is a characteristic of the Perdido formation, which was first described for the Quartz Spring area. Dark limestone in the lower part is distinguished from the Tin Mountain limestone by some beds of shale and some beds of dark chert, and the top of the formation is marked by a thin bed of fossiliferous limestone lying on reddish- or light-gray, very soft shale. The siltstone, and vitreous quartzite produced from it by contact metaphorism, weather yellowish brown or reddish brown. The conglomerate, which is local, is made up of cobble- and boulder-size constituents of the same lithology (except shale) as in other parts of the Perdido formation. It may mark a disconformity, accounting for a wide diversity in thickness of the formation. Details of the lithology, as well as the thickness, vary greatly from place to place; in general the Perdido formation in the southwestern corner of the quadrangle is thinner and contains more limestone and much less shale and siltstone than in the northeastern corner and beyond, at the type locality, where it is about 600 feet thick. The Perdido formation is Mississippian in age as indicated by early Mississippian fossils (Williams and Duncan *in* McAllister, 1952, p. 24) at the base and late Mississippian fossils in the topmost bed. Although the formation occurs widely in the quadrangle, it contains almost no mineral deposits. The Shirley Ann lead-copper deposit in the Dodd Springs area probably is in the Perdido formation in a zone of metamorphosed undifferentiated Paleozoic rocks.

#### Rest Spring Shale

Overlying the top bed of limestone in the Perdido formation, the Rest Spring shale (fig. 6) is sharply distinguished by its dark-gray shale, which weathers olive

FIGURE 6. Rest Spring shale under Bird Spring(?) formation. The smoother slope formed on Rest Spring shale, in a canyon about 5 miles due west of the Ubehebe mine.

gray, and which near the base contains a few discoidal argillite concretions around septarian cores. The shale grades upward into siltstone, which at the type locality in the Quartz Spring area contains a little quartzite and a few thin pebbly conglomerates. The Rest Spring shale in general is characterized by the dark-gray or olive-gray color, the fine-grained texture, and the quick weathering to small chips. Because it is incompetent and was folded, sheared, or intruded, measurements of the thickness are not reliable. In a long exposure from the western side of the Ubehebe Peak intrusive mass to the northern edge of the quadrangle, the outcrop width of a nearly vertical highly sheared zone ranges roughly from 200 feet to 1,000 feet, but on the flank of an open fold west of Lee Flat the Rest Spring shale is about 300 feet thick. The Pennsylvanian(?) age assigned to the Rest Spring shale has not been verified by the few poorly preserved fossils (Williams *in* McAllister, 1952, p. 26) collected from it but is a tentative designation based largely on the stratigraphic position just above late Mississippian fossils and a short distance below probably middle Pennsylvanian fusulinids. Lithologically it is much more like shales interbedded in the overlying Pennsylvanian and Permian formation than like any rock in the Mississippian formations. None of the mineral deposits are in the Rest Spring shale.

#### Bird Spring (?) Formation

A great thickness—well over 5,000 feet—of limestone, shale, and local conglomerate of Pennsylvanian and Permian age is questionably referred to the Bird Spring formation. Hewett (1931, pp. 21-30) established the unit, of Pennsylvanian age, in the Goodsprings district, Nevada, and it has been used extensively in southeastern California. Much of the Bird Spring(?) formation in the Ubehebe Peak quadrangle (fig. 10) contains rocks that are similar in lithology and age to the type Bird Spring formation, but the use of the name in the quadrangle is questioned because thick Permian rocks, which contain much shale, limestone, and some conspicuous limestone conglomerate, are expediently included in the formation. In the Ubehebe Peak quadrangle, partly sandy and partly pebbly limestone greatly predominates over the interbedded shale throughout the lower part, about 3,500 feet thick, whereas shale greatly predominates over interbedded limestone and lenticular beds of limestone conglomerate through an unknown thickness in the upper part. It is the most extensively exposed Paleozoic formation in the quadrangle, although it occurs almost entirely in the western half. Fusulinids in the lower part of the formation are Pennsylvanian and early Permian(?) and those in the upper part are unquestionably Permian (Henbest, written communication, 1952). The predominance of limestone continues upward into unquestionable Permian strata. Throughout the region only the basal limestones in the Bird Spring (?) formation contain distinctive spheroidal black chert nodules. Some of the thicker interstratified shales resemble the underlying Rest Spring shale, but the Rest Spring shale has been distinguished from them by the small spheroidal chert nodules in the limestone above the shale and by the discoidal argillite concretions in the lower part of the Rest Spring shale.

The uppermost part of the Bird Spring(?) formation makes a landmark of rugged cliffs around the

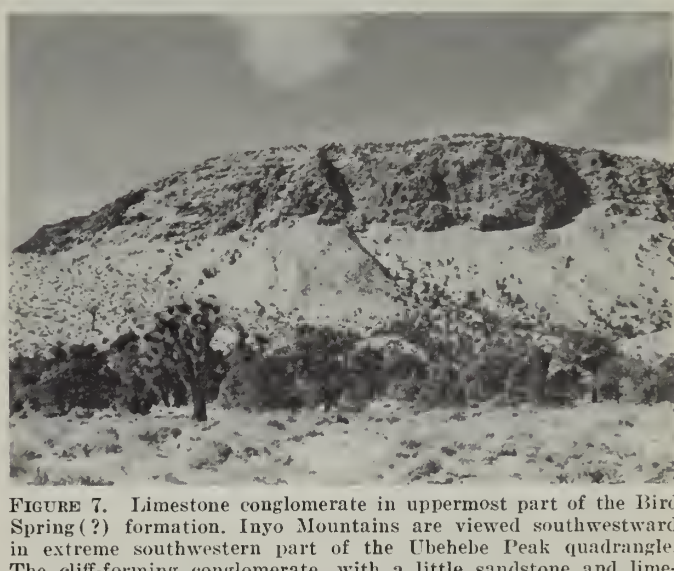

FIGURE 7. Limestone conglomerate in uppermost part of the Bird Spring(?) formation. Inyo Mountains are viewed southwestward in extreme southwestern part of the Ubehebe Peak quadrangle. The cliff-forming conglomerate, with a little sandstone and limestone at base, probably is here locally thrust over a shaly part of the Bird Spring(?) formation.

mountain in the extreme southwestern corner of the Ubehebe Peak quadrangle (fig. 7). Here it consists of limestone conglomerate, at most about 600 feet thick, lying on some sandstone and sandy limestone, and under some calcareous sandstone. The top is eroded. The constituents of the conglomerate, ranging in size from sand to small boulders, were derived perhaps entirely from the lower part of the Bird Spring(?) formation. Silicified zones transgress some parts of the limestone conglomerate, but the conglomerate contains no mineral deposits here and lies far from the small copper deposits that occur in the lower part of the Bird Spring(?) formation in the Nelson Range.

#### Basalt and Sedimentary Deposits of Cenozoic Age

A great gap in the sedimentary record separates the rocks of Paleozoic age from those of late Cenozoic age. Pliocene or early Pleistocene fanglomerate and olivine-basalt and extensive younger sediments lie unconformably on rocks of Paleozoic age and plutonic rocks of Mesozoic age. The rocks of Cenozoic age concern metalliferous deposits only to the extent that they may cover deposits. Placer gold has not been reported, nor are there any known interbedded deposits of other minerals. Very few metalliferous mineral zones are overlapped by the edge of the extensive Cenozoic capping. A rare example is the zone of well-developed quartz veins that contains the copper deposit of the Copper Queen-Lucky Boy mine; it extends to the basalt capping at the southern foot of the Nelson Range. On a broader scale the whole zone of widely spaced small deposits of copper or lead north of Lee Flat may extend toward the Lee mine in the Darwin quadrangle, constituting a favorable zone for mineral deposits buried under an unknown thickness of material deposited in Cenozoic time.

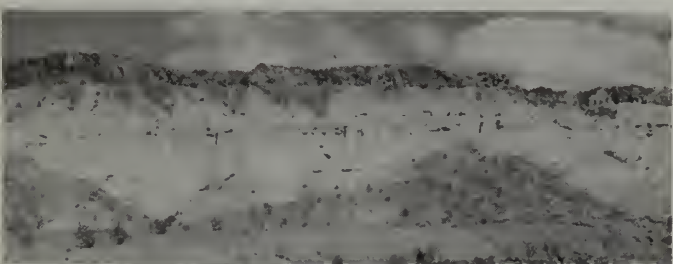

FIGURE 8. Cenozoic fanglomerate capped by olivine-basalt in cliff 3 miles northwest of Ubehebe Peak.

The oldest exposed rock of Cenozoic age is fanglomerate under scoria and flows of olivine-basalt (fig. 8). Although as much as several hundred feet thick at some places, it thins to a few feet under some of the olivine-basalt or pinches out completely. A little of the scoria, which is entirely basaltic and includes volcanic bombs, transects the flows and probably marks volcanic vents, but most of it lies under the flows and grades downward into fanglomerate. The constituents of this fanglomerate include recognizable fragments of many Paleozoic formations, quartz-monzonite, and other plutonic rocks. Lake sediments are associated with the fanglomerate at one large exposure. Some other old alluvial fan material lies above the olivine-basalt in Grapevine Canyon and was tilted and faulted along with the olivine-basalt. A great thickness of tilted gravel is partly exposed between the Inyo Range and the Nelson Range, but the relationship of this gravel to the olivine-basalt has been obscured by faults, more recent alluvial deposits, and slope rubble. The olivine-basalt consistently has phenocrysts of olivine and is somewhat varied in structure; much of it is vesicular or amygdaloidal. Only remnants of the original covering of olivine-basalt and old gravel remain in the quadrangle, in contrast to the thick sections and broad expanses in the adjacent region toward the south and southeast, where there should be better clues to the sequence and age of these deposits.

Small areas of loose water-worn cobbles and boulders are isolated high on some mountains, both near and far from old bedded fanglomerate. Some of the material has been locally let down from higher positions, as in the Lippincott mine area. It is not known, however, to what extent the gravels at the other places have been reworked to lower levels or are residual at the original locations; and if residual, whether they are remnants of widespread deposits that buried a hilly topography or remnants merely of deposits along drainage channels to the former bajadas represented by the old gravel under the basalt.

The greatest part of undisturbed Quaternary sediments consists of alluvial fan material, but there are some partly dissected lake deposits in Saline Valley, playa deposits in Racetrack Valley and Hidden Valley, and concentrations of wind-deposited sediments in Saline Valley and on some mountainsides.

#### Intrusive Rocks

The Paleozoic sedimentary rocks were intruded by a quartz-monzonite batholith and by smaller satellite masses. Some of the small masses that are now surrounded by alluvium may be exposures of either the batholith or satellites. Quartz-monzonite is by far the main kind of intrusive rock in the quadrangle, but other kinds occurring at some places along margins of the batholith and in the satellite masses include: granite, syenite, monzonite, syenodiorite, diorite, olivine-gabbro, gabbro, syenogabbro, aplite, pegmatite, and minette. Among these, only the olivine-gabbro, gabbro, and syenogabbro contain essential minerals that are not in quartz-monzonite. The others differ from quartz-monzonite mostly in the proportions of minerals or essential lack of one or more of the minerals that occur in quartz-monzonite. Some of these less abundant intrusive rocks, being closely related to contacts of the quartz-monzonite with the Paleozoic rocks, are disproportionately common in the areas of mineral deposits.

The mineral compositions of widely spaced characteristic samples of the principal masses of plutonic rock are well grouped within the limits of quartz-monzonite, if it is defined as a granitic rock containing potash feldspar at least 35 percent but not more than 65 percent of the total feldspar, and quartz at least 5 percent of the felsic minerals. The potash feldspar in this quartz-monzonite normally is orthoclase, in part microperthitic, and the plagioclase is oligoclase or andesine. The mafic minerals, commonly between 3 and 20 percent of the total volume, are hornblende, augite and biotite. Of these, hornblende occurs the most persistently and in the greatest proportion. The quantity of hornblende ranges from accessory to as much as 14 percent of the volume of 32 specimens among the 34 quartz-monzonite specimens that were nicrometrically analyzed. Biotite is an accessory mineral n nearly all the analyzed specimens of quartz-monzonite, out only in two is it at least 5 percent of the volume. Augite is an accessory in five of the specimens and ex-ceeds 5 percent of the volume in none. Sphene, magne-ite, and apatite are accessory. Much of the quartz-nonzonite is very light colored, having less than 5 per-ent dark minerals. The texture of the quartz-monzonite varies from medium-grained to very coarse grained, the oarser-grained texture having locally subparallel elon-gate grains of feldspar.

Some coarsely porphyritic rock has a sufficiently large proportion of orthoclase phenocrysts in a quartz-mon-onite groundmass to make it quartz-poor granite. A vell-defined mass of the porphyritic granite is about ,000 feet in diameter, north of Ubehebe Peak. A large utcrop of the porphyritic granite is readily accessible t The Grandstand in the northern end of The Race-rack playa (see fig. 2). Here tabular phenocrysts of Carlsbad-twinned orthoclase, commonly about 2 inches ong and 0.2 inch thick, are alined in a conspicuously rachytoid texture. The phenocrysts appear to be closely packed in a quartz-monzonite groundmass but according o the few measurements made they compose only some-what more than a quarter (about 28 percent) of the olume. The granite—phenocrysts and groundmass com-bined—consists of about 58 percent potash feldspar, 30 percent plagioclase, 6 percent quartz, 4 percent horn-blende, 1 percent sphene, and 1 percent total of augite, biotite, apatite, and magnetite. A few small copper de-posits northwest of Ubehebe Peak are in marble at the ontact with the coarsely porphyritic granite.

Syenite, coarse-grained and medium-gray, commonly ccurs in apophyses and in highly irregular masses be-ween quartz-monzonite and marble. Orthoclase, which is iversely microperthitic, makes up more than 90 percent f the volume, and melanite is one of the principal dark ninerals. The largest exposure of syenite is near the Ubehebe and Copper Bell mines, and a little syenite rops out in the Sally Ann area. Minette dikes in the Ubehebe mine can be considered a mafic variety of the yenite, in which nearly half of the volume is coarse biotite, one-seventh is aegirine-augite and only one-third s potash feldspar.

Syenodiorite is another variation from quartz-monzo-ite that occurs at the mineral deposits, such as at the Lost Burro mine and in the Sally Ann area. The texture f this medium-dark rock within short distances is var-ed: medium-grained, coarse-grained, or porphyritic in which the phenocrysts are augite or poikilitic biotite. The proportion of orthoclase, by the definition here followed, s less than 35 percent but at least 5 percent of the eldspar. There is no quartz in this syenodiorite, and the proportion of augite and biotite together is high. With a greater proportion of orthoclase, but not more than 65 percent of the feldspar, the rock is monzonite, such as he augite monzonite in the foothills on the western side f Hidden Valley, southeast of the Big Rock claim (see fig. 2). Monzonite and syenodiorite in a moderately large area southeast of the Dodd Springs grade into syenogab-bro, olivine-bearing monzonite, and olivine-gabbro. Only ome small copper deposits in the Dodd Springs area lie n the contact zone next to the gabbroic mass.

The age of the plutonic rocks, as indicated by cross-cutting relationships within the quadrangle, is younger than Permian and considerably older than late Cenozoic. The rocks are probably the same age as the nearby similar plutonic rocks that cut across Triassic rocks in the Inyo Range and that Knopf and Kirk (Knopf, 1918, pls. 1 and 2) designated on their maps as Early Cretaceous, and they are probably the same age as the plutonic rocks in the Sierra Nevada, which have been called, however, Late Jurassic as well as Early Cretaceous.

#### Metamorphic Rocks

At the contacts of the plutonic rocks the Paleozoic rocks are irregularly metamorphosed principally to marble, calc-silicate rock, hornfels, and quartzite. The mineral assemblages in the metamorphic rocks are varied and only a few are described here. Others associated with any particular mineral, and some of the localities, are more fully described in the annotated list of minerals arranged alphabetically at the end of the report.

Marble is the most voluminous contact-metamorphic rock in the area. It consists of calcite or dolomite, or combinations of both, and it is bleached nearly white or to shades of gray much lighter than in the original formations. Some of the least bleached and recrystallized dolomite contains scattered bundles of tremolite. In some of the cherty dolomite the nodular chert was metamorphosed to clots of tremolite or rims of tremolite around cores of diopside. Small parts of the dolomite marble are dedolomitized to greenish-yellow antigorite, minute veinlets of chrysotile, and calcite. Dolomite marble, containing thin beds of quartzite, is the host rock of the Lippincott mine lead-zinc-silver ore. Some small copper deposits extend into marble adjacent to tactite.

Light-colored calc-silicate rock is abundant, especially where sandy, silty, and shaly limestone of the Bird Spring(?) formation extends into the contact-metamorphic zone in the Nelson Range. Commonly the fine-grained, light grayish green calc-silicate rock is composed of plagioclase, diopside, wollastonite, and accessory sphene and magnetite. Some of it at the intrusive contact contains coarser diopside as a major constituent, which in a zone of mixed rock is associated with prehnite and albite, or with zeolites, epidote, and alkalic feldspars. The mixed rock in general contains much albite and epidote. Metalliferous mineral occurrences are scarce and economically unpromising in the light-colored calc-silicate and mixed rocks.

Dark-colored calc-silicate rock, or tactite, is much less abundant than the marble and light-colored silicate rock. The tactite is characterized by iron-bearing garnet, idocrase, and epidote, and in some places it contains magnetite, pyrite, chalcopyrite, and minerals produced from them by oxidation. Many of the light-colored silicates, as well as calcite and quartz, occur in or closely associated with the tactite, making difficult the distinction of tactite. Most of the copper deposits and a small deposit of coarse scheelite occur in tactite or in closely associated contact-metamorphic rock.

Hornfels from shale and shaly siltstone of the Rest Spring shale crops out extensively along the western border of the Ubehebe Peak mass of quartz-monzonite and in San Lucas Canyon about 1½ miles from the nearest outcrop of plutonic rock in the Nelson Range. The horn-


FIGURE 9. View north-northwest across Racetrack Valley in the northeastern part of the Ubehebe Peak quadrangle, showing the strat graphic throw along the Racetrack thrust fault. Racetrack dolomite (Cambrian) in hill left of center is thrust eastward over Perdid formation (Mississippian) next to the conspicuous belt of Rest Spring shale in the lowest saddle.

fels in San Lucas Canyon contains small but noticeable crystals of andalusite in the form of chiastolite, in a fine-grained matrix of quartz, biotite, and carbonaceous material. Quartzite was formed from thin-bedded sandstone and siltstone in the Lost Burro and Perdido formations exposed in the Lippincott area as well as north of Ubehebe Peak and south of the Lost Burro mine. The more massive Eureka quartzite in the contact zone appears similar to typical Eureka quartzite. The hornfels and massive quartzite do not contain any of the mineral deposits.

### Structure

The Paleozoic rocks were folded and thrust-faulted before they were pushed aside and contorted by intrusive masses of Mesozoic quartz-monzonite. Deep erosion was followed by local deposition of fanglomerate and then an outflowing of olivine-basalt. Intermittently during further deposition of continental sediments, regional warps have yielded along faults, making the present closed basins and mountain blocks.

The only major angular unconformity that has been recognized truncates the Mesozoic plutonic rocks and highly deformed Paleozoic rocks, and lies under tilted or nearly horizontal upper Cenozoic rocks. Hiatuses in the Paleozoic sequence are difficult to find and to evaluate because of inadequate fossil preservation. Disconformities and probably local angular unconformities occur in the Carboniferous and Permian rocks.

Folds in the Paleozoic rocks in the northern part of the quadrangle trend north, but southwestward beyond a wide expanse of alluvium in Saline Valley and quartz-monzonite in the Nelson Range, folds trend northwest. The broadest fold, which is an anticline between the Ubehebe Peak mass of quartz-monzonite and the northern boundary of the quadrangle, exposes westward-dipping beds for 2½ miles from Racetrack Valley across the higher part of the mountains. The eastern limb of the anticline, which is largely concealed by alluvium in Racetrack Valley, is overturned along a thrust fault. West of the broad anticline, other folds are smaller, and they plunge south into Saline Valley.

Some of the folds in the northeastern part of the quadrangle pass into thrust faults and steep reverse faults. The largest, which is called the Racetrack thrust fault, is poorly exposed from near the northern boundary of the quadrangle for about 7 miles southward along the eastern side of Racetrack Valley. Northward from the quadrangle the Racetrack thrust fault emerges from alluvial cover near Quartz Spring and makes the known length about 13 miles. The overturned limb of a large anticline along the thrust is exposed in the broad foothills 1½ miles north of The Racetrack playa, where Pogonip limestone dipping gently west lies on Eureka quartzite. Here the Eureka quartzite is thrust over greatly deformed Rest Spring shale and Perdido formation, making the stratigraphic throw about 4,500 feet. Where the thrust fault is more continuously exposed south of The Racetrack playa, the maximum stratigraphic throw is about 8,000 feet, from the Racetrack dolomite to the Perdido formation (fig. 9). The southern end of the thrust fault is cut off by the batholith at Hunter Mountain. The Racetrack thrust fault contains none of the mineral deposits; copper deposits in the underlying contorted zone are directly related to intrusive contacts rather than to the thrust fault.

The regional north-trending folds and the Racetrack thrust fault apparently were greatly deformed by the dynamic intrusion of quartz-monzonite. The fault and some folds under it, where they lie between the Lost Burro mine and The Racetrack playa, are bent from the trend due south to a trend due east along the northern border of quartz-monzonite in the Sally Ann mass. At the southern end of the same mass, folds in the Tin Mountain and Lost Burro formations are bent eastward and back again, as if the folds had been plastically forced northward by the quartz-monzonite mass in Hunter Mountain. The trend of close folds in the Bird Spring(?) formation in the northwestern part of the Nelson Range makes a sigmoidal curve that is roughly parallel to the curvature in the trend of the contact with quartz-monzonite. The most greatly convoluted beds lie at the northern contact of quartz-monzonite in the Ubehebe Peak mass, where the intrusive contact is normal to the strike of nearly vertical beds in the Lost Burro formation. The axes of the convolutions are nearly vertical, and the degree of distortion rapidly diminishes away from the contact and through a zone as much as a mile wide, as though the beds had been plastically shouldered aside by the quartz-monzonite.

Some faults and local fractured zones also were apparently made by the intruding masses of quartz-monzonite, probably from still fluid cores making final adjustments along the solidified borders. Marble along these faults and in the breccia zones is recrystallized nearest the intrusive contacts, but some of the fractures continue into the quartz-monzonite. Minerals were deposited in some of the fractures on both sides of the intrusive contacts.

Younger faults contain incoherent breccia and gouge. Many of them, including those that displace mineral deposits in the mine areas, are sufficiently old to show no displacement of the topography. The major late faults cluster in zones at some places, such as along the flank of the Nelson Range facing Saline Valley, and displace the topography possibly thousands of feet. The most recent faults are expressed by faint scarps across alluvial fans in Saline Valley.

Ore-controlling parts of the regional structure are minor faults, shattered zones, and possibly some favorable beds, generally within contact-metamorphic aureoles or within intrusive rocks near the contacts.

## MINERAL DEPOSITS

### History and Production *

The Ubehebe mining district was organized July 8, 1875, when 8 locations were on record, according to Lt. Rogers Birnie, Jr. (Wheeler, 1876, pp. 284-285). He credited William Hunter of Cerro Gordo with discovering the first ore, which contained copper carbonate and some silver, on the northern slopes of the mountain that trends at right angles to the main part of the Panamint Range and separates Panamint Valley from Saline Valley. Mr. Hunter opened the Ulida mine, from which he transported high-grade ore by means of burros (Shorty Borden, oral communication, 1949). As early as

* Production figures, unless otherwise indicated, are from annual records made available by the U. S. Bureau of Mines, Metal Economics Branch, San Francisco office. The writer, however, is responsible for compilations.

1895, land in Saline Valley was staked for borax, and somewhat later, borax works were constructed (Gale, 1914, pp. 420-421). Some of the borax that was recovered probably came from the part of Saline Valley now in the Ubehebe Peak quadrangle. By 1902, when the California State Mining Bureau investigated the copper resources of the state, there was considerable activity on scattered copper properties in the Ubehebe mining district; about 80 claims were located within a radius of 6 miles (Aubury, 1902, pp. 245-248). The gold deposit at the Lost Burro mine was discovered, according to the owner (Wm. C. Thompson, written communication, 1952), in 1905 by Andy McCormick and Bert Shively when they were hunting lost burros. Despite the isolation and aridity, interest in the copper deposits increased between 1902 and 1908 (Aubury, 1908, pp. 301-312), and a wagon road was built from the mining district to the railroad at a place between Bullfrog and Tonopah in Nevada. Until much later, only trails led to Keeler on the railroad in Owens Valley and to other California outlets. Much of the ore was therefore shipped to Nevada and some was combined with ore from Nevada mines, obscuring the record of early production from mines in the Ubehebe district.

The figures given here for the known production from mines now in the Ubehebe Peak quadrangle, which includes mines outside of the old Ubehebe mining district, should be considered minimum quantities. The different sources of ores were not always discriminated in combined shipments nor always clearly described by some of the early shippers. This may account for the failure to find a record of production from some of the small mines and the major part of the production from the Lost Burro gold mine. A conservative estimate of the unrecorded early production of gold from the Lost Burro mine, for example, is 2,000 ounces. The quantity of zinc contained in the ores from the district was not reported during the earlier years because the zinc at that time was not worth recovering. Some old assays nevertheless suggest that there was as much zinc in the ores then as there is in the ores now. The recorded content of metals in 4,788 tons of ore mined in the Ubehebe Peak quadrangle during the period 1908-1951 follows: 332 ounces of gold, 44,729 ounces of silver, 120,180 pounds of copper, 2,657,559 pounds of lead, and 164,959 pounds of zinc.

The first recorded production from mines in the quadrangle was 491 ounces of silver from the Ubehebe mine in 1908, and the next production was in 1913 from the same mine, which yielded 39 tons of ore containing 2 ounces of gold, 1,268 ounces of silver, 135 pounds of copper, and 35,374 pounds of lead. The Ubehebe mine has produced also the greatest quantity of lead in a single year, 1,120,343 pounds of lead in the ore mined during 1928. Subsequent annual production of lead from the quadrangle has not surpassed 145,000 pounds. The maximum annual production of copper has been 82,000 pounds, in the ore mined from the Anton and Pobst mine during 1916, and since 1930 the annual production of copper has exceeded 1,000 pounds only in 1948. Silver has been mined more steadily than the other metals, reaching a maximum annual production of 15,222 ounces in the ore mined during 1928 but not exceeding 3,700 ounces in any later year. The Ubehebe mine has the longest history of production, with a broad gap in mining between 1931 and 1946, and shorter gaps at other times. The most continuous mining in recent years has been at the Lippincott mine, from which no production was recorded for only two of the years (1939 and 1942) between 1938 and 1952.

### Types and Distribution

The mineral deposits in the quadrangle are broadly grouped as metallic and nonmetallic, according to the nature of the ultimate product. The description of the nonmetallic deposits is short because almost none have been exploitable. Bulky materials, such as limestone, dolomite, and aggregate, are commercially unattractive in their isolated situation, for similar materials elsewhere in the region are found much nearer a railroad and markets. Less bulky nonmetallic materials that are sufficiently valuable to be exploited despite the isolation have not been found, are of insufficient quantity, or are of poor quality.

The metallic mineral deposits are mostly in veins and in poorly defined replacements of local shattered zones near intrusive contacts. The hypogene (primary) deposits range from pyrometasomatic, such as the occurrences of scheelite, magnetite, and some of the copper minerals, to mesothermal, such as the principal lead-zinc-silver deposits. Supergene (oxidized) deposits derived practically in place are abundant and are predominantly all that remain exposed in mine workings, obscuring the original, hypogene characteristics.

Mineral deposits are widely distributed in the mountains that define Racetrack Valley; farther south a few are grouped in the Dodd Springs basin, and some others are in the Nelson Range north of Lee Flat. The three most extensively mined deposits are at the Ubehebe mine, the Lippincott mine, and the Lost Burro mine, which are from 4 to 8 miles apart in the first area. All the deposits, as far as known, are small.

#### Nonmetallic Deposits

*Salines.* In the bottom of Saline Valley some old lake sediments are impregnated with salines, which are locally concentrated into efflorescences. Part of the saline material is borate-bearing. Land was staked for borax in Saline Valley as early as 1895 (Gale, 1914, pp. 420-421), and a few years later it was recovered from sediments that yielded perhaps as much as 90 percent borax (Bailey, 1902, p. 49). It is not known whether borate deposits were exploited partly within the Ubehebe Peak quadrangle or entirely outside. A grab sample of lake sediment from the northwestern margin of the quadrangle contains white aggregates and disseminated grains of ulexite, identified by R. D. Allen (written communication, 1953). According to a chemical analysis by Henry Kramer (written communication, 1953), the sample contains 1.45 percent $B_2O_3$. The source of the borate is not yet known. Although hot springs, such as those in the northeastern part of Saline Valley, cannot be disregarded as the primary source, a possible source is an older lake sediment that was deposited during a period of volcanic activity. Some of this sediment, which is of late Pliocene or early Pleistocene age, remains in foothills about 1,200 feet above the floor of Saline Valley. A grab sample contains 0.06 percent $B_2O_3$ (Henry Kramer, analyst, 1953). Meteoric water possibly carried traces of borate from the older sediment into the bottom of Saline Valley, where the borate was concentrated by evaporation.

No beds of salines have been exposed by shallow erosion of the lake sediments in the part of Saline Valley that lies within the quadrangle. A brine lake and surrounding crusts of salt in the lowest part of the valley lie beyond. The small playas at The Racetrack and in Hidden Valley have no exposed saline deposits nor efflorescence. The older continental sedimentary rocks appear to contain only traces of salines.

*Talc.* Only one talc deposit is known to occur in the quadrangle. It is on the Homestake claim of R. B. Walls, about 2,000 feet northeast of the Lippincott mine, and appears not to have been exploited. The talc, which is mottled bluish gray, irregularly replaced the dark, cherty, lower unit of the Ely Springs dolomite about 3,000 feet from the nearest exposed contact of intrusive rock. The quality of talc in this small deposit was not determined.

Less than a mile beyond the eastern border of the quadrangle, in hills east of Ulida Flat, two talc deposits replaced dolomite in the Pogonip limestone near small exposures of plutonic rocks. A talc deposit 2 miles farther east (about 1 mile north of Goldbelt Spring) also is a replacement of dolomite that probably is in the Pogonip limestone. The talc in these three deposits, said to be of steatite grade, was mined by means of small underground workings during World War II.

All the talc deposits are hydrothermal replacements of dolomite within 1½ miles of the exposed margin of a quartz-monzonite batholith and close to isolated apophyses from it. The talc-bearing dolomite, where not siliceous itself, is near cherty, silty, sandy, or quartzitic beds; therefore other occurrences of dolomite associated with siliceous beds near intrusive rock favor prospecting. Exposures of Pogonip limestone near intrusive contacts southeast of the Ubehebe mine area, northwest of the Lippincott mine area, and north of the Dodd Springs area probably are the most favorable places to prospect for steatite-grade talc.

*Asbestos.* Chrysotile asbestos occurs in stringers through antigorite in some of the contact-metamorphic zones. The stringers are thin; although some are microscopic, others on fresh surfaces of the rock are clearly visible by the silky luster of the transverse fibers, which are as much as 0.1 inch long. The enclosing pale to dark greenish yellow antigorite, conspicuously more abundant than the chrysotile in it, is a guide in prospecting for chrysotile asbestos. Some aggregates of antigorite, chrysotile, and calcite, constitute ophicalcite and were formed by the dedolomitization of silty dolomite, as in parts of the Hidden Valley and Lost Burro formations. Minor occurrences of chrysotile were noticed in the Lippincott and Sally Ann areas, and somewhat better occurrences are in the hills east of Ulida Flat, barely outside the eastern boundary of the quadrangle.

An example of ophicalcite is found in the originally somewhat siliceous dolomite beds in the hill facing the Lippincott mine. A thin section of the ophicalcite shows antigorite in irregular aggregates intergrown with and surrounded by calcite, and in a very few aggregates that are bounded by 4 or 8 straight sides as if they were pseudomorphs of euhedral crystals. The original euhedral crystals may have been forsterite, which commonly precedes the serpentine minerals during dedolomitization, but no unaltered forsterite remains to prove it here. Diopside in elongate anhedral grains shows no signs of alteration. Chrysotile and some intergrown calcite are in veinlets that cut across the rock. Water at a relatively low temperature, using silica already in the rock, probably converted some dolomite directly to antigorite, chrysotile, and calcite. Whatever forsterite may have formed earlier, at a higher temperature, was also converted to serpentine minerals.

#### Metallic Deposits

General aspects of the metallic mineral deposits grouped according to commodities are summarized here and details are treated in the descriptions of the mines and prospects. Minerals of the ore deposits are included also in the annotated list of minerals.

*Lead-zinc-silver.* The lead-zinc-silver deposits, which are the only ones that have sustained a small exploitation through recent decades, are the principal metallic deposits in the quadrangle. There are few lead-zinc-silver deposits but they are widely spaced through the middle of the quadrangle from the Ubehebe mine at the northern border to the Lippincott mine near the center, the Shirley Ann mine farther south near Big Dodd Spring and finally to the Cerrusite mine and other small deposits around it in the Nelson Range.

The hypogene ore minerals in the lead-zinc-silver deposits are silver-bearing galena and less sphalerite. They are associated with pyrite and sporadic chalcopyrite or tetrahedrite. Little of the sulfide part remains exposed in the mine workings or at outcrops, since the miners have generally left only the weathered borders. The supergene minerals of lead here are mostly cerussite, traces of anglesite, and locally abundant wulfenite and arsenian vanadinite. The zinc supergene minerals seen are hemimorphite and hydrozincite. Limonite, in large proportions at some places, is associated with the lead and the zinc supergene minerals. At a few places they are accompanied by supergene copper minerals, such as malachite and more commonly chrysocolla. The wulfenite and arsenian vanadinite suggest that the hypogene ore assemblage is more complex than the few samples that have been seen; no molybdenite, which probably is the source of the molybdenum for the wulfenite, and no hypogene minerals that provide arsenic and vanadium for vanadinite, have been seen in the ore deposits.

Gangue is relatively scarce in the larger ore shoots, where the waste is principally quartzite or dolomite country rock, some of which is silicified, or granitic rock, which is somewhat sericitized. Calcite and quartz are the principal gangue minerals; others include brown jasper, gray chalcedony, some clay minerals, dolomite, aragonite, and traces of gypsum or of antigorite and chrysotile.

Some of the galena and sphalerite replaced quartzite and dolomite marble, and some filled cavities of fissures and breccias. It is not known which process predominated, but it seems probable that replacement was the more effective one.

The grade of the ore shipped from the Ubehebe mining district has been high in lead and silver and low in zinc. During the period from 1908 to 1950 the recorded content of lead in the ore averaged about 22 percent with about 9 ounces of silver per ton. Ore shipped earlier in the period was much higher grade, as it averaged more than 30 percent lead, and some contained as much as 55 percent lead. The content of zinc, which was first recorded in 1946, averaged nearly 5.5 percent zinc, but some ore contained at least 18 percent zinc.

The ore shoots are irregularly lenticular or pod-shaped, and their attitudes range from nearly horizontal to nearly vertical. The longest dimensions of mined ore shoots, as indicated by stopes lined with oxidized ore minerals, range from a few feet to 110 feet. The largest ore shoot, mined from the south stope in the Ubehebe mine, was at most about 110 feet by 20 feet by 12 feet. The outlines of rather widely separated shoots in the Ubehebe mine lie within a vertical range of 80 feet in a block about 500 feet long and 200 feet wide. In the main workings of the Lippincott mine, a succession of steep and nearly continuous pods constituted a pipe-like zone through a vertical distance of about 250 feet. Other lead deposits in the Lippincott area are widely spaced in an area about 2,200 feet long and 500 feet wide.

Ore-controlling structures are minor elements in the regional structure, and they are obscured by supergene alteration in the stoped zones. The structural features that localized the ore in the Ubehebe mine are particularly obscure. In the lower stopes they appear to be gently dipping minor fractures that lead out from a steep fault, which in the higher stopes is mineralized. Some ore was controlled by fractures along minette dikes. In the Lippincott and Shirley Ann areas, minor steep faults and shattered zones controlled the lead-zinc-silver deposits. Also the lead deposits in the Cerrusite mine were localized by minor fault zones.

The country rock of the lead-zinc-silver deposits is Paleozoic dolomite, dolomite marble interbedded with a little quartzite, or calcite marble interbedded with a little shale, or Mesozoic quartz-monzonite. The deposits are in a different formation at each mine area: the Ely Springs dolomite at the Ubehebe mine, the Lost Burro formation at the Lippincott mine, possibly the Perdido formation at the small Shirley Ann mine, the Bird Spring(?) formation at minor occurrences in the Nelson Range, and quartz-monzonite at the small Cerrusite mine. Thus with so few deposits it cannot be said that any particular formation favored the deposition of lead and zinc minerals; nevertheless, fractured dolomite several hundred feet from an intrusive mass was the most favorable environment for the lead-zinc-silver deposits.

*Gold.* Gold ore has been mined only from the Lost Burro mine, in the northeastern corner of the Ubehebe Peak quadrangle. The geology of the gold occurrence, therefore, is described in the section on the Lost Burro mine. A very small quantity of gold has been recovered from the lead-zinc-silver deposits. The few ore samples that were cut from some of the copper deposits, according to assays by D. L. Skinner of the U. S. Geological Survey (written communication, 1950), contain only traces of gold or none.

*Copper.* Copper was the first metal in the region to attract the general attention of prospectors and miners, late in the last century. The difficulty of working deposits isolated in desert mountains was recognized even during an early period of exaggerated optimism about the size of the deposits. Although the production of copper has been small, copper properties in the Ubehebe district have been listed in reports on the copper resources of California (Aubury, 1902, pp. 245-248; Aubury, 1908, pp. 301-312; Eric, 1948, pp. 238-252) and in several on the mineral resources of Inyo County (Waring and Huguenin, 1919; Tucker, 1926; Tucker and Sampson, 1938; Norman and Stewart, 1951). Many of the old properties, however, were not identified from the brief published descriptions or from claim notices, which are gone. In recent years the only mining activity on a copper property has been at the Sally Ann, which produced no copper. The small copper production recently has been a by-product of the lead-zinc-silver mines.

The copper deposits are widely scattered in the Ubehebe Peak quadrangle within a belt about 6 miles wide and 15 miles long, trending S. 25° W. from the northeastern corner of the quadrangle. Most of them are in contact-metamorphic zones, such as at the border of the stock east of the Ubehebe mine, at the northern and southern borders of the Ubehebe Peak stock, widely spaced around the borders of the Sally Ann intrusive mass and satellites north of it, in the septum at the Dodd Springs, and in the Nelson Range at the southwestern border of the Hunter Mountain batholith. A noteworthy exception is a copper deposit in a quartz-calcite vein within quartz-monzonite near the intrusive contact a mile south-southeast of the highest peak in the Nelson Range. A few quartz veinlets in quartz-monzonite at other places and some pegmatitic masses have traces of copper minerals.

The copper deposits in tactite and the associated marble are within a few feet of intrusive contacts with quartz-monzonite or its border facies of syenite and syenodiorite. Contact metamorphism obscured many diagnostic characteristics of the formations that contain the deposits, but enough characteristics remain in some to trace them into known formations, which range through the stratigraphic column from the Pogonip limestone of Early Ordovician age (as at the Copper Bell mine), through the Ely Springs dolomite of Late Ordovician age (Inyo Copper Smelting and Mining Co.), the Lost Burro formation of Devonian age (the Ulida, Blue Jay, and Sally Ann), questionable Tin Mountain limestone or Perdido formation of Mississippian age (Shirley Ann and others in the Dodd Springs area), and the Bird Spring(?) formation of Pennsylvanian and Permian age (the group in the Nelson Range). The oldest part of the local sequence, the Racetrack dolomite and the Nopah formation, and the youngest part, the Permian uppermost part of the Bird Spring(?) formation, are not known to be in contact with the intrusive rock and have no copper deposits; neither has the Eureka quartzite nor the Hidden Valley dolomite, which have short exposed intrusive contacts. The Rest Spring shale, despite an intrusive contact 2½ miles long west of Ubehebe Peak, also lacks copper deposits. Thus marble of no particular formation or age, but especially if somewhat impure, favored the copper mineralization.

The conspicuous copper minerals that remain in the deposits are malachite, chrysocolla, and a little azurite, but there is also some chalcopyrite, chalcocite, covellite, bornite, and cuprite. The associated metallic constituents are mostly magnetite, limonite, and hematite; there also is some pyrite, galena, and a little scheelite, some of which is stained with cuprotungstite. The gangue minerals are brownish and reddish jasper, some translucent light-gray chalcedony, quartz, calcite, and typical constituents of contact-metamorphic calc-silicate rocks: dark garnet of varied colors, idocrase, epidote, light-colored pyroxenes, scapolite, wollastonite, antigorite, chrysotile, and phlogopite.

The copper, along with the tungsten of the scheelite, was introduced probably during the last part of the contact-metamorphic processes, continuing after the intrusive rock was sufficiently consolidated to hold veins. Iron, possibly along with silica, was provided earlier for the iron-rich calc-silicate minerals of the tactite and for magnetite and quartz, but continued to be available for pyrite and chalcopyrite, accompanied by quartz. Chalcedony, drusy quartz, and perhaps much of the jasper formed very much later, after the supergene copper minerals; colloform chalcedony and drusy quartz incrust malachite and copper silicates.

The copper deposits are small, but the grade of mined ore probably was high. One mine, for example, in 1918 produced 45 tons of ore that contained 14,748 pounds of copper, or about 16 percent copper. The total recorded production of copper, although not large, is hard to explain by what remains in the small workings unless some of the deposits had rich supergene concentrations that were completely mined.

*Tungsten.* Some scheelite has been found in tactite and other contact-metamorphic rocks at several places in the Ubehebe Peak quadrangle. Tactite occurs widely in the quadrangle, but a large part of it is in rough country that is isolated from the few roads and probably has not been thoroughly prospected with an ultraviolet lamp. The known scheelite in contact-metamorphic rock here occurs in or near rock that has some copper minerals. Traces of scheelite in calc-silicate rock were seen in the southern part of the Sally Ann area, in the southeastern corner of the Lippincott area, and a few hundred feet west of the Copper Queen-Lucky Boy mine (but not in the mine) in the Nelson Range. A somewhat greater quantity of coarser-grained scheelite occurs on the Cuprotungstite claim north of Big Dodd Spring. Scheelite has not been found in the principal mines.

A few medium-sized grains of scheelite occur in a thin syenite pegmatite in quartz-monzonite, about 4,500 feet northeast of Big Dodd Spring. It is here associated with albitized orthoclase, which constitutes most of the dike, and some melanite, magnetite, and epidote.

Minerals of the wolframite series have been reported in a vein in granitic rock at the Monarch mine: huebnerite was specified in an early report (Waring and Huguenin, 1919, p. 131) and black wolframite in a late compilation (Murdock and Webb, 1948, p. 313), but ferberite is indicated by the abundance of iron and scarcity of manganese in a spectrographic analysis of a typical specimen from the dump (H. W. Johnson, analyst, written communication, 1953). The ferberite of the Monarch mine occurs in quartz-calcite veinlets in a thin lode that fills fissures in somewhat argillized quartz-monzonite of the batholith at Hunter Mountain. Limonite and stain from supergene copper minerals occur in some parts of the lode, and copper prospects lie within a few hundred feet of the mine. The tungsten ore shoot ended at a depth of 50 feet in the shaft (Waring and Huguenin, 1919, p. 131), which was inaccessible when examined in 1953; the ore shoot does not crop out beyond the shaft.

Figure 10. Ubehebe mine area, view north. Ely Springs dolomite, irregularly bleached by contact metamorphism, constitutes the visible part of the mine ridge.

## MINES AND PROSPECTS

### Lead-Zinc-Silver

#### Ubehebe Mine

The Ubehebe mine (fig. 10), which is in secs. 1 and 2, T. 14 S., R. 40 E. (projected), crosses the northern boundary of the Ubehebe Peak quadrangle. The mine portal, at about 3,800 feet above sea level, is near the head of drainage to Saline Valley, west of a low place in the Racetrack Valley divide. It is at the end of a dirt road nearly a mile from the road junction on the western side of Racetrack Valley, about 23 miles from paved road at Ubehebe Craters, and a total of 64 miles from the junction with California Highway 190 in Death Valley.

The nearest water is the small supply at Quartz Spring in the Panamint Range on the east side of Racetrack Valley, about 7 miles from the mine. No springs or seeps are known in the bare mountains around the mine, or anywhere between Racetrack Valley and Saline Valley. Operators of the Ubehebe mine formerly piped a scant flow from Quartz Spring to a storage tank at the end of the spring road, and then hauled the water to the mine. Improved roads and transportation have made it practicable to truck water from the better supply at Goldbelt Spring or even from the copious supply at Scotty's Castle at the northern end of Death Valley (see fig. 1).

The Ubehebe mine area (pl. 1) was mapped by plane table along a stadia traverse, and the main workings were mapped by tape and Brunton, with the assistance of A. F. Agnew in 1947. The small north workings and south workings were mapped with the assistance of E. M. MacKevett in 1951. The maps were oriented by compass and the initial altitude was determined by aneroid but later was adjusted approximately to the topographic map of the Ubehebe Peak quadrangle. The extent of the mapped mine area is based on the relevant geology and not on ownership of mining property.

*History and Production.* The mineral deposit at the Ubehebe mine was presumably discovered the year of the first ore shipment, in 1908, for L. E. Aubury's thorough review of mining properties in the Ubehebe district, published in 1908, does not mention any deposit at the location of the present Ubehebe mine and his index map of the district (Aubury, 1908, facing p. 300) does not show mining claims at this locality. The Ubehebe mine was called the Farrington mine when the next production, for 1913, was recorded. During later years the mine was also called Waterson or Butte, and in 1928 ore from the Copper Bell mine was included with ore from the Butte mine. Although Butte and Copper Bell have been retained in the names of the mining claims, Ubehebe has been used without variation for the name of the mine since 1938.

The earliest known published description of the Ubehebe mine (Waring and Huguenin, 1919, p. 109) states that in the spring of 1916 the ore body of what is called the south workings in the present report was being mined from an adit 60 feet long, and by then it was nearly worked out. The adit at that time was connected to a lower adit, which later became the main entrance to the mine, but no other ore bodies had yet been opened from the lower adit. The deposit near the top of the ridge, on the northern side, was then known but apparently was unworked. The owner in 1916, W. W. Waterson of Bishop, employed 3 men and contracted to have the ore hauled by tractor 52 miles to Bonnie Claire, Nevada. The difficulty of hauling ore in those days is recorded in the statement that the round trip required 52 hours.

Annual production of the Ubehebe mine * has been sporadic, except from 1927 to 1930 (inclusive) and from 1947 to 1949 (inclusive), but not as stagnant as implied by some of the early reports on mining activity in Inyo County (Tucker, 1921, p. 294; 1926, 501). The most copper produced in any year was mined by J. H. Crook during 1918. He reported developing during the same year some zinc carbonate ore that assayed 48 to 53 percent zinc, but the zinc content of shipped ore, which was not recorded until 1947, has since that year averaged about 7 percent zinc. The quantity of lead mined annually first surpassed 100,000 pounds in 1921. After a lapse of 6 years the production of lead was increased during 1927 by H. D. Fenkell, P. D. Fenkell, and J. C. Dahlstrom, who shipped oxidized ore containing an average of nearly 65 percent lead and 17 ounces of silver per ton. They leased the mine from Arch Farrington, J. H. Crook, M. E. Albert, S. S. Arentz, and the Montana Tonopah Company Reorganized. The maximum production of lead and silver in the history of the mine was reached the following year, 1928, when the same lessees shipped 1,002 tons of ore that contained 1,120,343 pounds of lead and 15,222 ounces of silver. This burst in production attracted the attention of the Salt Lake Tribune, which on February 21, 1928, published that Dahlstrom and the Fenkell brothers of Tonopah, leasing the mine from Crook and Farrington, made $16,-

* The following information about production, except where sources are otherwise indicated, was compiled from annual records in the San Francisco office of the Metal Economics Branch, U. S. Bureau of Mines. Published by permission of Grant Snyder, President, Ubehebe Lead Mines, Inc.

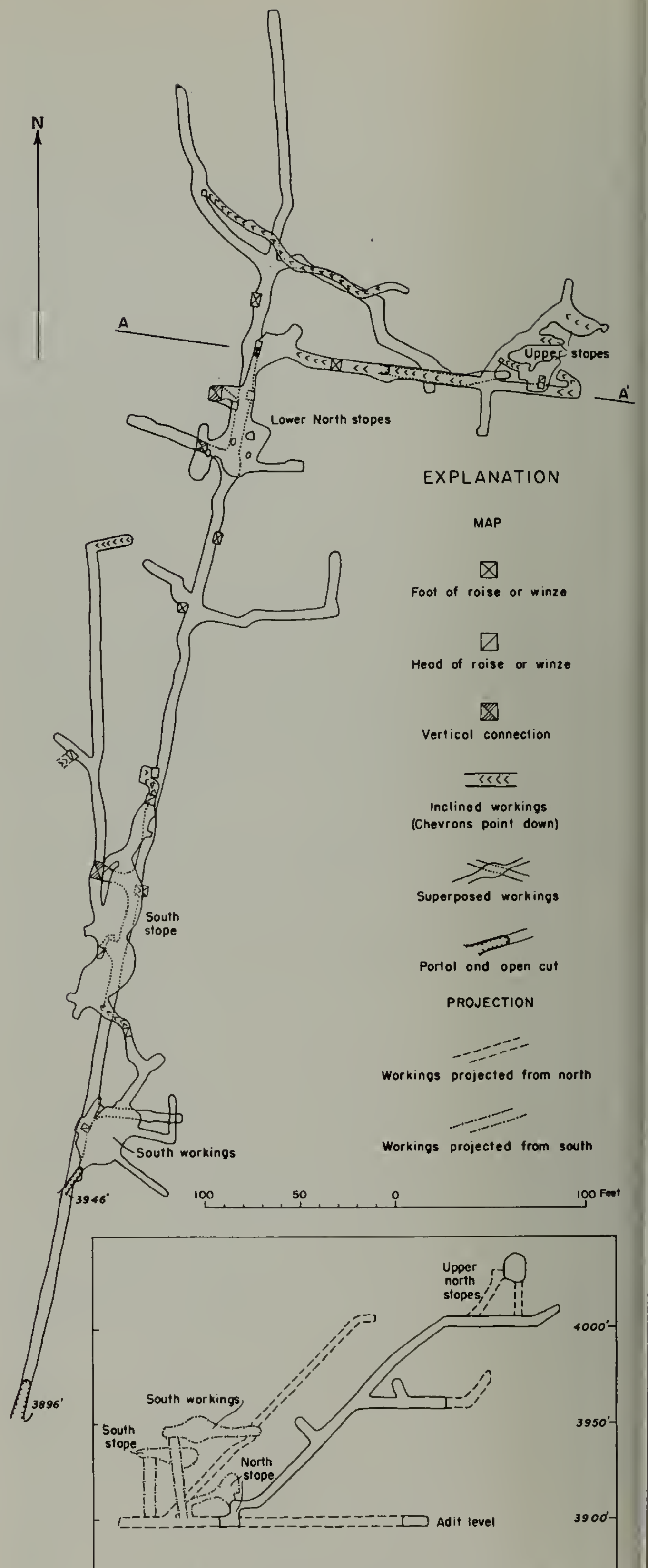


FIGURE 11. Composite map and projection of connected workings in the Ubehebe mine.

*Recorded metallic content of ore shipped from the Ubehebe mine.*
*U. S. Bureau of Mines, Metal Economics Branch, San Francisco Office*

| Year | Ore tons | Lead pounds | Zinc pounds | Silver ounces | Copper pounds | Gold ounces | Name used for mine |
|---|---|---|---|---|---|---|---|
| 1908 | 48 | | | 491 | | | Ubehebe |
| 1913 | 39 | 35,374 | | 1,268 | 135 | 2 | Farrington |
| 1914 | 24 | 19,000 | | 711 | | | Farrington |
| 1916 | 254 | 78,304 | | | | | Waterson |
| 1918 | 45 | | | 5 | 14,748 | | Ubehebe |
| 1921 | 259 | 283,865 | | 7,984 | 1,023 | 7 | Ubehebe |
| 1927 | 258 | 331,183 | | 4,498 | | 2 | Butte |
| 1928 | 1,002 | 1,120,343 | | 15,222 | 1,523 | 17 | Butte, Copper Bell |
| 1929 | 22 | 21,505 | | 156 | | | Butte |
| 1930 | 69 | 48,000 | | 963 | 6,870 | 3 | Butte |
| 1938 | 86 | 51,473 | | 482 | | 3 | Ubehebe |
| 1947 | 111 | 13,875 | 19,930 | 171 | 669 | 1 | Ubehebe |
| 1948 | 245 | 102,404 | 53,854 | 1,337 | 1,141 | 3 | Ubehebe |
| 1949 | 99 | 39,652 | 11,568 | 311 | 277 | 2 | Ubehebe |
| 1951 | 379 | 104,460 | 37,390 | 1,313 | 38 | | Ubehebe |
| Total | 2,940 | 2,249,438 | 122,742 | 34,912 | 26,424 | 40 | |

000 in 25 days, from 12 carloads of lead carbonate ore. Production dropped abruptly during the two following years, after which mining was suspended for seven years. In 1937 Grant Snyder and C. A. Rankin leased the mine from the Farrington estate, employed 10 men, and shipped ore by truck to Death Valley Junction (Tucker and Sampson, 1938, p. 456), thus producing some lead and silver in 1938. After another inactive period, from 1939 to 1946, mining was resumed in 1947 and has continued under the ownership of Ubehebe Lead Mines, Inc., of which Mr. Snyder is president.

*Mine Workings.* The Ubehebe mine workings (figs. 11 and 12) consist of the main workings, opening from the portal that is near the canyon floor; the south workings, opening from a portal on the hillside about 45 feet higher than the main portal and 100 feet north of it; the north workings, about 175 feet north of the crest of the mine ridge and about 200 feet higher than the main portal; and several small prospect adits, shafts, and pits. The south workings, which are probably the oldest ones, connect underground with the main workings, but the north workings are isolated. None extend below the main adit level.

The main adit, which enters the hillside nearly straight for about 725 feet, connects with four principal stopes (fig. 11). For convenience of reference these stopes are called (1) the upper north stopes, which are from 105 to about 140 feet above the adit level, (2) the lower north stope, which is from about 10 to 30 feet above the adit level, (3) the south stope, 30 to 40 feet above the adit level, and (4) the stope in the south workings about 50 feet above the adit level. The lower north stope is reached through short raises from the adit level, and from it the upper north stopes are accessible through a 45° incline about 135 feet long. A steep incline about 150 feet long from the adit level farther north does not connect with the higher workings. The south stope has a 135-foot vertical connection with the adit level and an irregular inclined connection through the south workings to the surface.

The stopes are generally flat lying. Their area very roughly is 5,000 square feet, and their volume even more roughly is on the order of 35,000 cubic feet. The total length of the main and south workings, irrespective of stopes, is about 1,950 feet, which added to about 350 feet in the north workings makes about 2,300 feet of workings. Short exploration adits east of the main workings have not exposed any ore.

*Rocks.* The ore deposits are in the Ely Springs dolomite within 400 feet west of a steep fault that placed the dolomite against the Eureka quartzite and the Pogonip limestone. The deposits lie 400 to 800 feet southwest of the exposed contact with syenite of a small stock. The stratigraphic sequence of the sedimentary rocks in the mine area consists of Lower Ordovician Pogonip limestone, Middle Ordovician Eureka quartzite, and Upper Ordovician Ely Springs dolomite. The Pogonip limestone, which lies in contact with syenite of the stock, is recrystallized and bleached nearly white by contact metamorphism. Unmetamorphosed limestone and dolomite in this part of the Pogonip elsewhere in the region are fine-grained and light gray. The Eureka quartzite is vitreous and nearly white except in the lower part, where it is stained yellowish and reddish brown by iron oxides. The contact of Eureka quartzite with the underlying Pogonip limestone in the southeastern corner of the mapped area is stratigraphic, dipping about 50° SW., but most other boundaries of the quartzite in the area are faults. The upper stratigraphic contact, with Ely Springs dolomite, is not exposed in the mapped area, and the nearest exposure is about 1,500 feet south of the mine area.

Ely Springs dolomite is by far the predominant rock of the mine area and contains all the ore deposits. The dolomite was recrystallized, somewhat bleached, locally stained with limonite, and shattered, so that it no longer has the typical appearance of the formation. Where unchanged, as in the eastern front of the mountains a mile south of the mine, the Ely Springs dolomite consists of a dark-gray lower unit 560 feet thick, which contains abundant chert nodules in the basal 250 feet, and of a light-gray upper unit 380 feet thick. The upper unit, about 200 feet below the top, has a conspicuous 15-foot layer of dark-gray dolomite that crops out in the Ubehebe mine area as a dark layer between 5 and 10 feet thick. The Ely Springs dolomite exposed in the mine area includes most of the light-gray upper unit and some of the dark-gray lower unit, but it is not exposed down to the most cherty part. The lower stratigraphic boundary, with Eureka quartzite, is concealed by faults, and the upper boundary, with Hidden Valley dolomite, lies a few hundred feet west of the mapped area.

The intrusive rock in the border zone of the small stock northeast of the Ubehebe mine is a leucocratic syenite composed almost entirely of perthitic orthoclase. Dikes that cut dolomite at the mine workings consist of minette. It is olive gray, contains conspicuously abundant biotite, and seems to be much finer grained than the syenite. The texture of the minette, however, is deceptive. Although biotite in a hand specimen appears to be the coarse constituent, a thin section shows that the biotite in thin flakes is poikilitically enclosed in subhedral feldspar grains that are commonly several times longer and many times thicker than the biotite flakes. Many of the biotite flakes are about 2 or 3 mm in diameter and some are as much as 7 mm. A thin section of fresh rock, cut normal to the general alinement of biotite, contains 45 percent biotite, 32 percent orthoclase and microcline, 14 percent aegirine-augite, 4 percent calcite, and 5 percent accessory sphene, apatite, and magnetite. Some of the minette dikes are associated with ore deposits in the Ubehebe mine, but it is not clear whether the relationship is partly genetic or entirely structural.

*Structure.* Stratification in the Ely Springs dolomite has been greatly obscured by contact metamorphism, but flat nodules of chert at a few places in the mine and a gray marker bed in the upper part of the formation suggest that the beds dip gently (10° to 15°) westward at the top of the ridge above the main adit, somewhat more steeply (about 20°) underground, and as much as 40° farther west.

The principal structural feature of the mine area is a steep preintrusive fault that strikes north and displaces the eastern block up relative to the western or mine block. Contact metamorphism by recrystallization and bleaching obscured the fault near the stock. The stratigraphic throw may be as much as 800 feet where middle Ely Springs dolomite lies against upper Pogonip limestone near the mine, but the throw rapidly decreases southward. It is difficult to trace the fault farther than half a mile south of the mine. The relative displacement upward on the stock side of the fault, the rapid decrease of displacement away from the southern exposure of the stock, and a change in trend and steepening of beds near the stock, suggest that the intrusive rock pushed up the eastern block.

Other faults in the area seem to be local, for they displaced markers—such as minette dikes, the gray bed in upper Ely Springs dolomite, and faults—only a few feet. Slivers of Eureka quartzite isolated in marble of the Pogonip and a poorly exposed patch of greatly brecciated Eureka quartzite in an area of Ely Springs dolomite (at the main saddle shown in pl. 1) are explained by faulting, although the circumscribing faults are obscure and poorly mapped. Some of the minor faults and the adjacent fractured rock probably furnished the channelways for the ore-bearing solutions.

Discontinuous dikes of minette crop out in a northwestward-trending zone about half a mile long and as much as 300 feet wide. Good exposures, especially near the top of the mine ridge, show that at the present topographic surface the dikes are actually discontinuous. Some dike segments are cut off by faults, but other segments express irregularities of the intrusive pattern. Irregularities occur also between exposures on the surface and in the mine workings. The minette altered readily and favored shearing, so that near the mineral deposits the dikes are faulted and brecciated.

*Ore Deposits.* The ore deposits that remain in stopes generally are incoherent, porous masses stained yellowish and reddish brown by iron oxides. They consist mostly of supergene minerals but still contain some rich cores of hypogene sulfides. Cerussite is the principal lead mineral; among the other supergene lead minerals, wulfenite is widespread and locally conspicuous in loose aggregates, and at some places arsenian vanadinite occurs as drusy encrustations. A little anglesite is closely associated with cerussite on galena. The common supergene zinc mineral of the deposits is hemimorphite rather than smithsonite despite the carbonate country rock. The zinc in hemimorphite presumably was derived from sphalerite, which now is inconspicuous. The source of lead in cerussite, on the other hand, is well shown by masses of coarse-grained galena embedded in cerussite. Among the few remaining hypogene minerals, none were seen that on oxidizing could provide molybdenum for the supergene wulfenite or arsenic and vanadium for the arsenian vanadinite. Minor constituents of the ore include pyrite and chalcopyrite disseminated in galena, some supergene copper minerals, and traces of a cinnabarlike mineral. The gangue, in addition to some silicified rock, is made up of earthy limonite and hematite, a little calcite, dolomite, quartz, and chalcedony.

Much of the cerussite is crumbly and mixed with limonitic material, but some is massive and grades from colorless through very light-gray to dark-gray masses that consist of minute opaque inclusions in translucent cerussite. At least some of these inclusions are galena and seem to be remnants of the original mass of galena. The darkest cerussite mixed with some anglesite forms borders around galena and stringers through it, often along the cleavage. The latest colorless cerussite, where subhedral and euhedral in vugs, crystallized at the same time as some of the wulfenite, but the bulk of the wulfenite covers the massive cerussite. Stringers of chalcedony and drusy quartz cut masses of cerussite, and drusy quartz envelops some euhedral crystals in wulfenite, showing that some quartz crystallized after cerussite.

Wulfenite, in thinly-tabular, yellowish-orange crystals commonly 2 mm. in diameter and in much less prominent minute elongate crystals, is as widely distributed as any other lead mineral in the Ubehebe mine, but there generally is little of it. Where most abundant, as in the upper part of the north stope, wulfenite makes a fragile crystal meshwork, which locally contains little else. Even in this part of the mine, earthy iron oxides are ordinarily mixed with the wulfenite crystals.

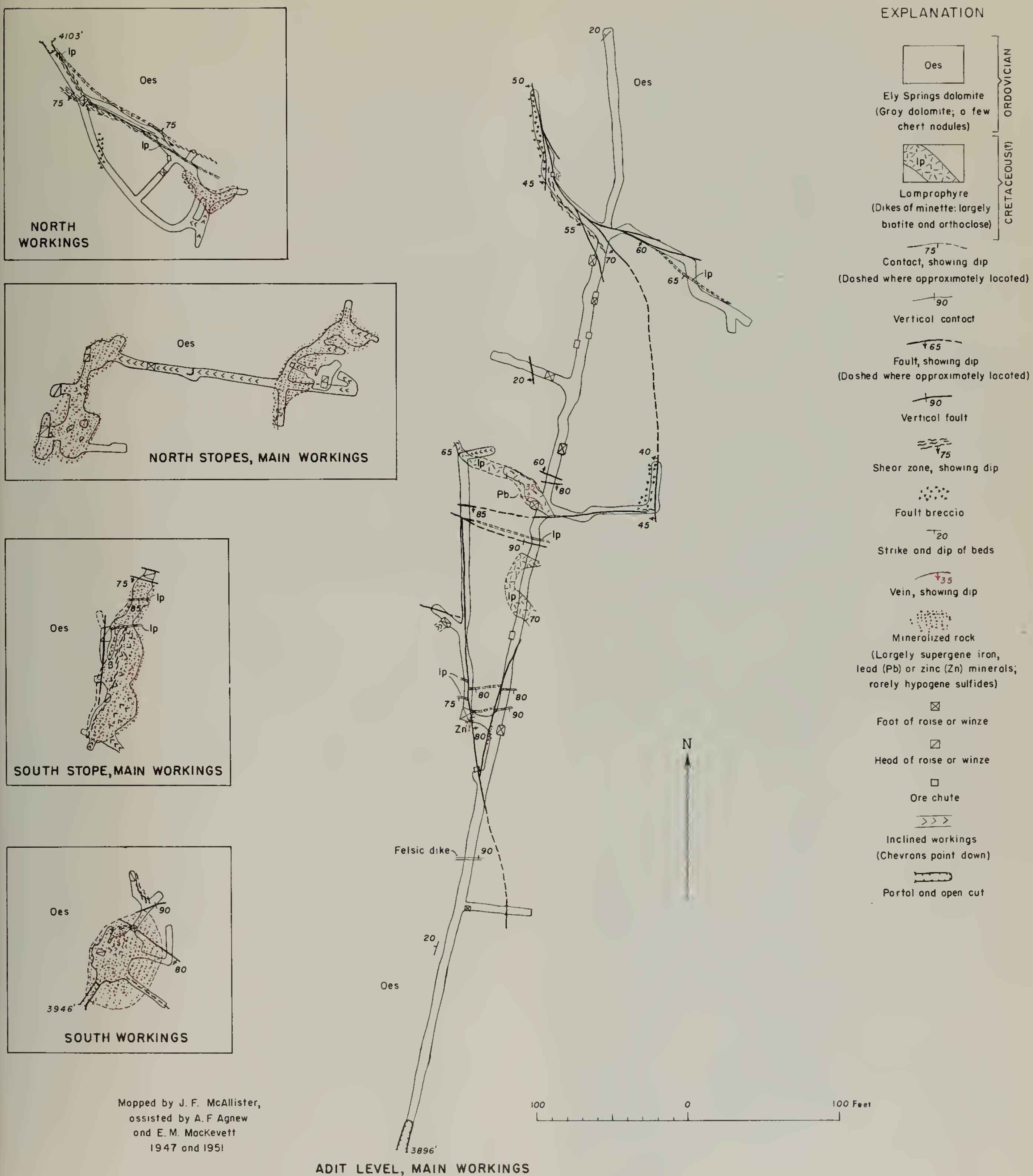


FIGURE 12. Geologic map of the Ubehebe mine.

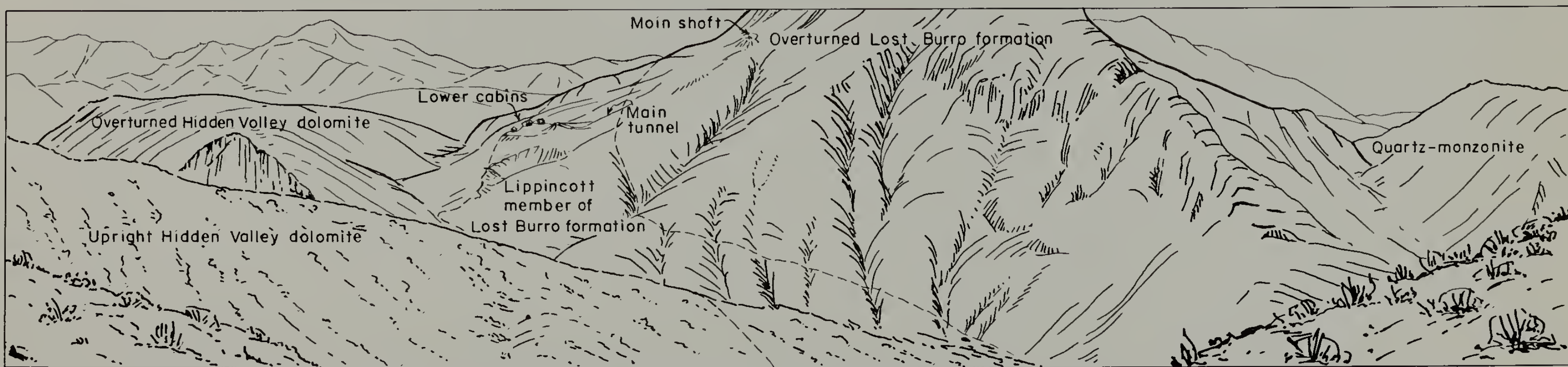


FIGURE 13. Lippincott area, view southeast. Hidden Valley dolomite is upright in left foreground and overturned in left middle distance; Lost Burro formation, including the basal, quartzitic Lippincott member, constitutes most of the central ridge; and quartz-monzonite lies on the right.

Arsenian vanadinite is less conspicuous than the wulfenite because the largest crystals are rarely as much as a millimeter long and are dark brown like some of the nearby limonitic material. The color of the vanadinite grades into golden yellow in the smallest crystals, and some unusual wheat-shaped grains are light greenish gray. Whatever the color, the mineral contains vanadium and some arsenic. Some of the brown arsenian vanadinite, according to a partial analysis by Henry Kramer (written communication, 1953), contains 10.84 percent $V_2O_5$ and 2.91 percent $As_2O_5$. Drusy crusts entirely of arsenian vanadinite were found in the upper north stopes, in much smaller quantity in the lower north stope, and in the south stope.

Hemimorphite occurs widely with the supergene lead minerals in the stopes, and was one of the last minerals to crystallize—at the same time as some of the wulfenite. Commonly the hemimorphite is in clear, delicate euhedral crystals, as much as 5 mm long and 3 mm wide, but at some places it is in coarse-grained aggregates that fill small cavities.

Hydrozincite. associated with some of the hemimorphite, makes white, fine-grained colloform linings and fillings in small cavities, and some is disseminated through the light-brown, hard argillaceous matrix. In dilute hydrochloric acid the hydrozincite effervesces, and in ultraviolet light it brightly fluoresces bluish white. The colloform structure consists of several concentric layers of radial slender grains commonly 0.2 to 0.5 mm long. The hydrozincite generally is earlier than the hemimorphite that occurs with it.

A red mercury-bearing mineral forms small clusters of microscopic acicular crystals at one place in the upper north stopes. Although the mineral contains mercury and resembles a form of cinnabar, the X-ray defraction pattern does not fit the standard of any mercury mineral (or lead oxide), according to F. A. Hillebrand (E. H. Bailey, written communication, 1953). As the cinnabarlike mineral occurs on cerussite, it is considered to be supergene. Only the cinnabarlike mineral, not the surrounding oxidized material nor the nearest galena, yields mercury in the sensitive mercury-vapor test by ultraviolet light on a willemite screen. Hewett (1931, pp. 81-82) describes cinnabar on cerussite or anglesite near galena in the Goodsprings district of Nevada. He suggests that the mercury was derived from galena by oxidation and compares it with supergene cinnabar derived from mercurian tetrahedrite in Oregon. Oxidation of a little mercurian tetrahedrite probably supplied the mercury for the trace of the cinnabarlike mineral in the Ubehebe mine, for mercurian tetrahedrite does occur in the district. Some is associated with galena in a thin quartz vein that cuts quartz-monzonite 2 miles southwest of Ubehebe Peak. The occurrence of the cinnabarlike mineral in the Ubehebe mine is merely a curiosity in a lead deposit of a region where no quicksilver deposits are known.

The highest grade of lead ore, according to 11 representative samples from the upper and lower north stopes and from the south stope of the main workings, is marked by some galena left in the oxidized mass or by unusually pure concentration of wulfenite. Silver in the assayed samples is even more closely tied to the galena; samples of what appeared to be entirely oxidized ore contain less than 3 ounces of silver per ton and most have less than 1 ounce per ton, whereas those showing some galena have more than 10 ounces and a sample across 1 foot of sulfide minerals contains as much as 44 ounces of silver per ton. But even in the oxidized ore the silver increases slightly with an increase in lead. Zinc shows the opposite relation; for example, a 1-foot sulfide vein consisting largely of galena, and containing 62.04 percent lead, assayed only 2.85 percent zinc, whereas a 2-foot sample across oxidized ore containing only 2.86 percent lead yielded the highest proportion of zinc, 44.84 percent. The ability of zinc to migrate much farther than lead during oxidation in this environment is illustrated by the hemimorphite lining cavities 50 feet below the stoped ore deposits.

The structural control of the ore deposits is concealed in the stopes by thorough supergene alteration, and few clues to it are revealed in the workings on the adit level below the stopes. Beds that strike parallel to the adit and dip about 20° W. or minor fractures of similar attitude may have controlled the deposits at the lower, flat-lying stopes. The alinement of these deposits, however, plunges 5°, N. 7° E., and may express an unseen structural control that acutely cuts the bedding.

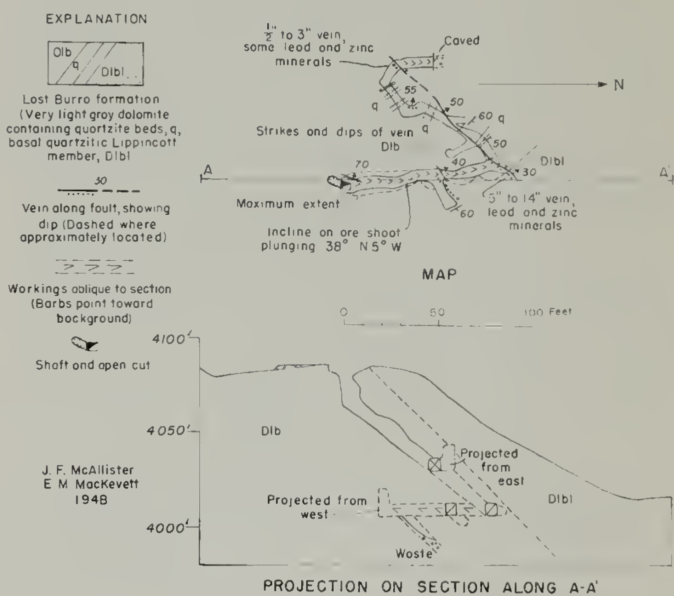


FIGURE 14. Map and projection of Addison workings, Lippincott mine.

No obvious channel for the ore solutions, that is, none containing lead ore minerals near the stopes, has been cut by the adit-level workings, which explore fairly well the ground under the stopes and north of them. One stringer of galena, less than an inch thick, is exposed on the adit level 180 feet from the portal and midway between the north stopes and the south stope. The stringer, which is in a minette dike, strikes west into the wall and dips 35° N., so that projected it leads to no stope. Hypogene ore solutions may have locally come down along a fault zone that follows an argillized minette dike

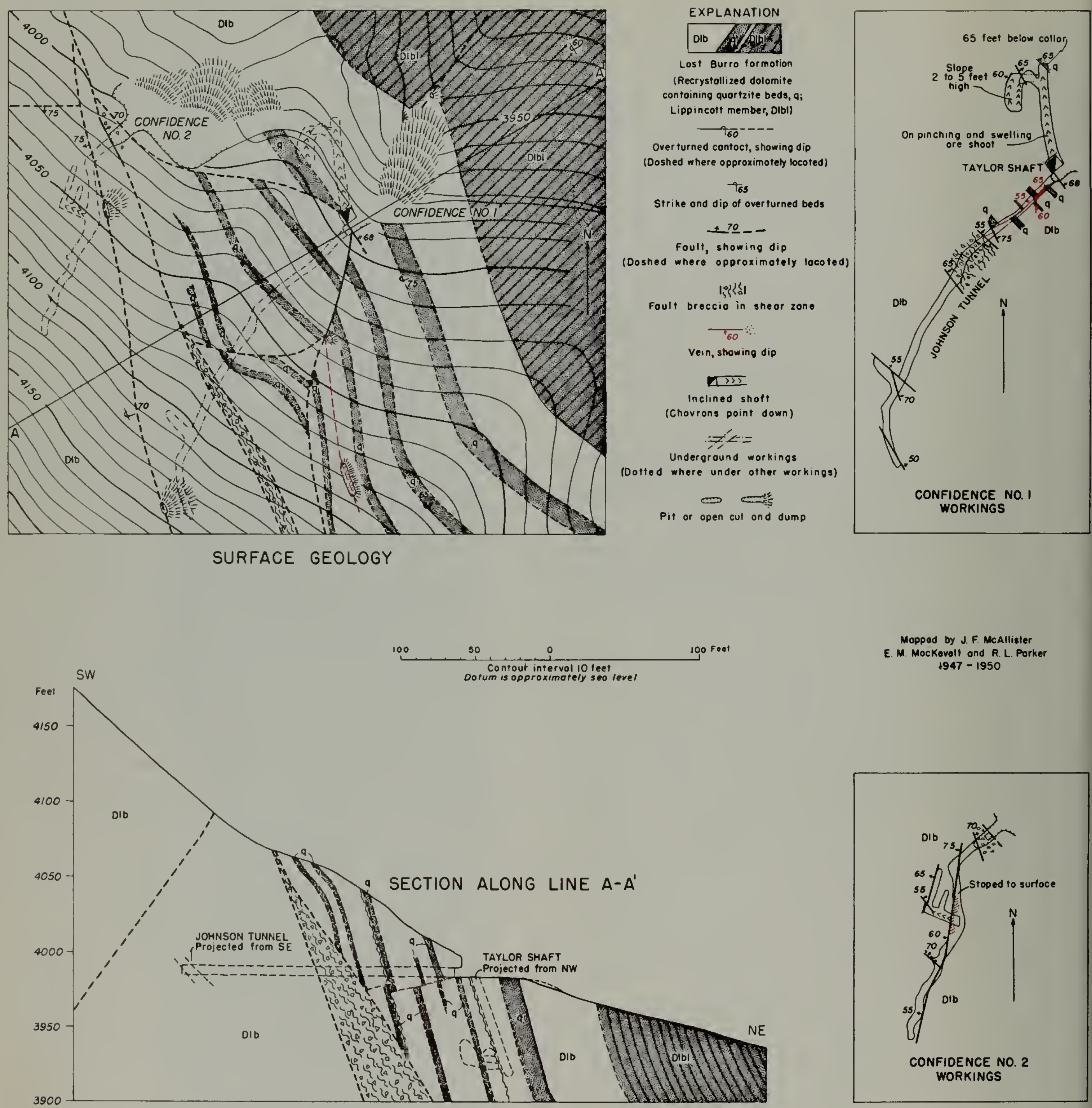


FIGURE 15. Geologic maps and section of Confidence workings, Lippincott mine.

between the upper and lower north stopes. Ore minerals occur also at the fault zone in the upper part of the northernmost incline on a level with and 50 feet west of the upper north stopes 100 feet above the adit level, and in shattered rock at what is interpreted as the same fault zone along minette dikes in the north workings about 100 feet still higher and 250 feet northwest of the incline. The plunge of the ore shoot 15° SE. from the surface for 120 feet in the north workings is toward the upper north stopes in the main workings, and suggests a high connection of ore channels. The same fault zone where well exposed on the adit level short distances north and south of the north stopes contains no ore minerals. It has not been explored, however, on the adit level beneath the north stopes, where discovery of ore minerals would favor exploration for lower ore bodies.

Structural features that account for the location of ore deposits at the south stope and the south workings also are poorly understood. On the adit level beneath these deposits steep faults, which displaced minette dikes very little, have no hypogene ore minerals. Supergene minerals form spottily distributed aggregates in the fault zones at the foot of the raise to the south stope and at the entrance to the crosscut to the raise. Here glassy-clear or white hemimorphite is conspicuous, particularly where crystals line or fill small cavities in limonite-stained rock. A little wulfenite crystallized with the hemimorphite. It is a characteristic of zinc to migrate in supergene solutions, forming hemimorphite under oxidized ore deposits, and of lead to remain near the original galena. Thus the occurrence of hemimorphite and the lack of anglesite, cerussite, and abundant wulfenite, show that the fault zones here were channels for supergene solutions but were not effective hypogene channels to the overlying ore deposit.

#### Lippincott (Lead King) Mine

The most continuous mining activity in the Ubehebe Peak quadrangle since 1940 has been at the Lippincott lead mine, which has been known also as the Lead King and as the Southern lead mine, and which is in sec. 13, T. 15 S., R. 40 E. (projected). The mining property, owned and operated by George Lippincott of Santa Ana, California, is 19 miles in a straight line N. 59° E. from Keeler and 4 miles south of Ubehebe Peak. The mine, which is about 4,000 feet above sea level, is on the north-facing side of the canyon that drains the southern end of Racetrack Valley into Saline Valley. From the mine it is 31 miles by an unsurfaced road through Racetrack Valley to a paved road that starts at Ubehebe Craters in Death Valley, and 125 miles farther to Lone Pine, which is on U. S. Highways 6 and 395. A more direct route 65 miles long to Lone Pine is over a rough, narrow, and steep road from Racetrack Valley, through the south end of Saline Valley, and up to paved California Highway 190 to Lone Pine. Over the shorter route it is advisable to use vehicles that have been well tested on rough mountain roads, and to anticipate washed-out places. The Racetrack playa has been used as a landing field nearly 3 miles long and about a mile wide.

The mine camp, constructed by Mr. Lippincott, consists of a unified group of six cabins near the main tunnel, and a more scattered group of three cabins southeast of all the mine workings. The camp has no local water supply so that all water has been hauled 26 miles from Goldbelt Spring or about 40 miles from Scotty's Castle. The nearest spring, Big Dodd Spring, is about 4½ miles by rough trail south of the camp. The spring, according to the topographic map of the Ubehebe Peak quadrangle, is about 3,880 feet above sea level whereas the mine camp ranges between 3,800 and 4,000 feet, and the highest place along the route between the spring and camp is slightly over 4,600 feet above sea level. Thus little pumping would be required to bring water from Big Dodd Spring to the mine camp, but the construction and maintenance of a pipeline able to withstand freezing would be difficult.

Around the mine an area of about 330 acres, 4,000 feet long and 3,600 feet wide, was surveyed with the assistance of E. M. MacKevett during parts of 1947 and 1948. The extent of the area is unrelated to boundaries of mining properties. The area was mapped by telescopic alidade and plane table, initially oriented by compass, on a scale of 1 inch equals 200 feet and with a 10-foot contour interval. The map is based on triangulation expanded from a baseline 1,190 feet long. The mine workings were mapped principally in 1947 and 1948, with the assistance of E. M. MacKevett, but were brought up to date in 1950 with the assistance of R. L. Parker. The mine maps were made by tape and Brunton compass, using the clinometer for vertical angles.

*History and Production.* The early history of prospecting and mineral development in the Lippincott area (pl. 2) is obscure because the names of mining properties have been changed several times, recorded descriptions of the locations are vague, and no claim notices dated prior to 1934 were seen at claim monuments. The earliest known published record (Aubury, 1908, p. 310) of a lead-silver deposit south of Ubehebe Peak refers to a north-trending vein in the Wedding Stake claim of J. H. Crook and Sam Baysdon from Keeler, California.* The Wedding Stake claim is the only mining property shown in this part of the Ubehebe district by the sketchy location map in the early report (Aubury, 1908, facing p. 300). Probably in the same area the Raven lead-silver mine was being developed in 1916, at which time the tunnel was 300 feet long, and 30 tons of ore, containing an average of 60 percent lead, was ready for shipment (Waring and Huguenin, 1919, p. 106). The Raven mine in 1916 was owned by J. Crook and A. Farrington. Subsequent reports of the California Division of Mines (Tucker, 1921, p. 293; 1926, p. 496; Tucker and Sampson, 1938, p. 451) before 1951 list the Raven as the only lead-silver property between Ubehebe Peak and Dodd Springs and as being idle. As recently as 1951 there was only one adit as much as 300 feet long south of Ubehebe Peak, the main tunnel of the Lippincott mine.

The earliest claim notices remaining in the Lippincott area show that P. E. Day held the Lead King mining claims in 1934. In 1935 and 1937 Roy Albin had the Contact Group of claims, as witnessed by P. E. Day. Then R. B. Walls and L. Walls acquired a quitclaim deed for the Lead King claims from P. E. Day in 1939. Their holdings included the old workings at the main tunnel and property that had been in the Contact Group. George Lippincott leased the Lead King property from Mr. Walls and started producing lead, silver, and a little gold in 1942. He bought the property in 1944 and has continued the production each year except 1945. Much of the ore, especially during World War II when lead was scarce, has been smelted by Mr. Lippincott in Santa Ana, California, for storage batteries. The zinc was not recovered in the smelter there. The high content of silver, at least during recent years, went with the lead into the storage batteries. The first record of the zinc content was for the production in 1946 (U. S. Bureau of Mines), when the zinc nearly equalled the lead; the proportion of zinc with respect to lead in the ore thereafter was very much lower.

*Mine Workings.* Except for part of the Main Tunnel, mine workings at the lead deposits were developed after

* According to Inyo County records, the Wedding Stake claim was located December, 1906, by J. H. Crook, Sim Boysdon, and Walter Clements.

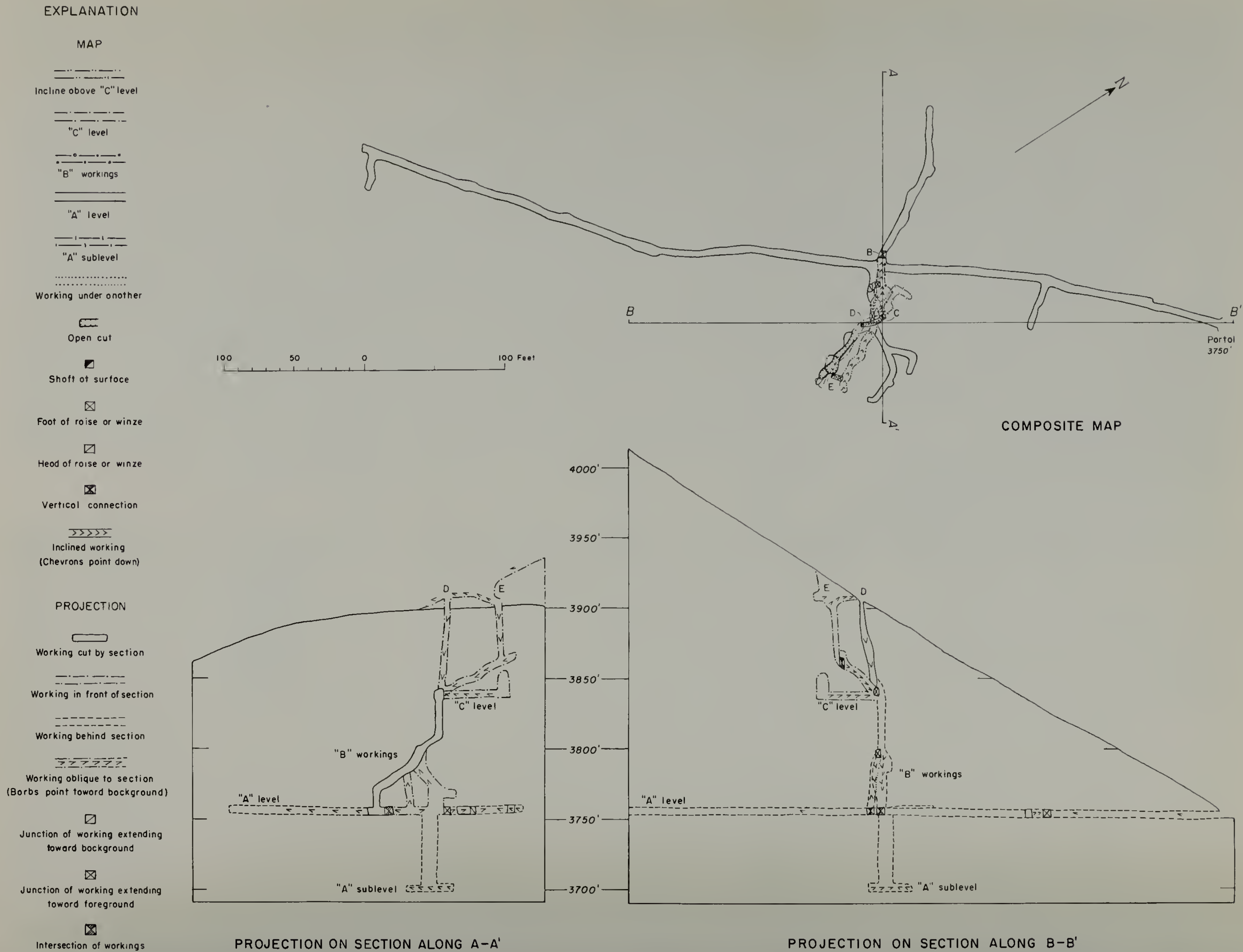


FIGURE 16. Composite map and projections of main workings, Lippincott mine.

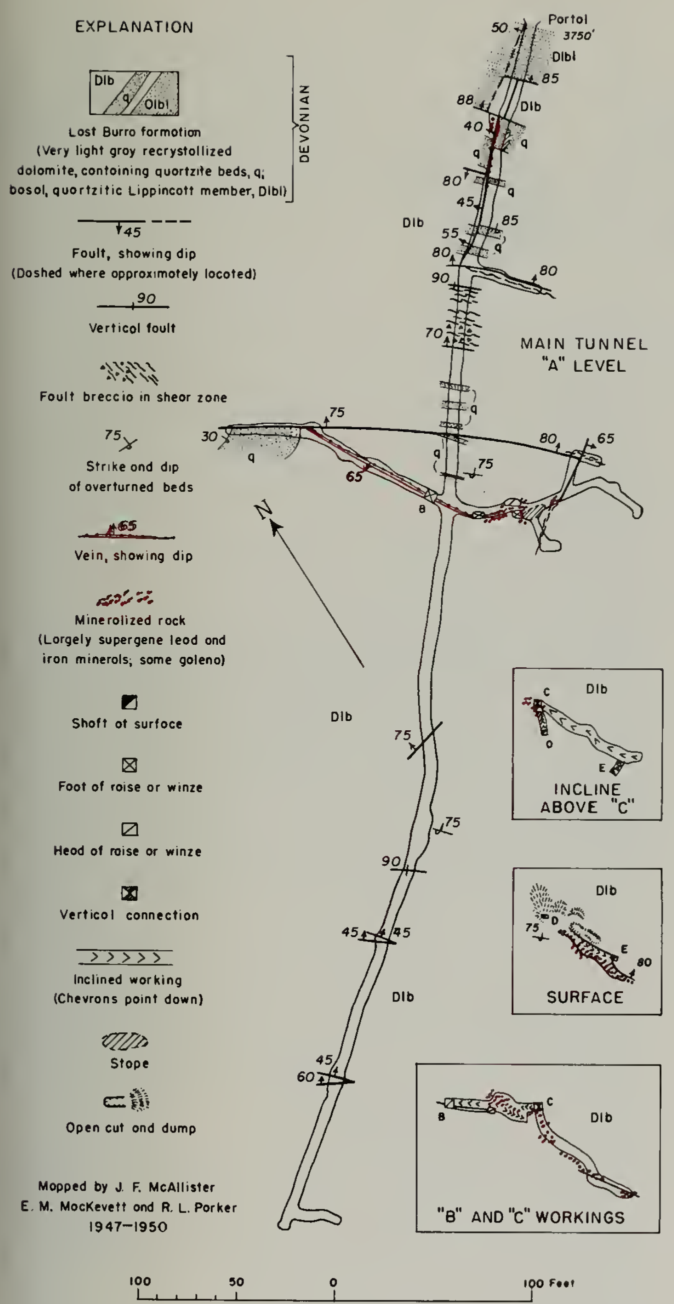


Figure 17. Geologic map of main workings, Lippincott mine.

Mr. Lippincott acquired the property. Ore was mined first from the main workings, then from the Addison workings, followed by the Confidence workings, and early in 1951 ore was being developed at the Inspiration shaft (see pl. 2). These separate workings are in a strip about 1,600 feet long and about 200 feet wide on the northeastern flank of a steep ridge. All descriptions refer to workings as they were in 1950. The main workings (fig. 16) contain an adit 625 feet long from which

Figure 18. View east-northeast toward the Cerrusite mine area. Portal of main workings (adit A) is at lowest dump. The Nelson Range here from the crest to the main workings consists of quartz-monzonite and its border facies.

drifts and other shorter workings amount to 320 feet; some inclined workings and subsidiary workings at several levels amount to 215 feet, through a vertical distance of about 225 feet. The Addison workings (fig. 14) consist of an incline about 120 feet long, lower inclines accessible for about 25 feet, and level workings 125 feet long, all together making about 270 feet. In the Confidence No. 1 workings (fig. 15) there is an adit (the Johnson Tunnel) 230 feet long and an inclined shaft (the Taylor shaft) about 100 feet long, or a total of about 330 feet of workings. The Confidence No. 2 workings (fig. 15) consist of an adit 150 feet long, 50 feet of subsidiary levels, and about 115 feet of inclined workings, totaling about 315 feet. The maps therefore show about 2,000 feet of level and inclined workings in the Lippincott mine.

*Rocks.* The Ordovician to Carboniferous sedimentary rocks in the Lippincott area were metamorphosed by a large intrusive mass of quartz-monzonite. The preponderant rock now exposed is dolomite marble that ranges in color from dark gray to yellowish gray or nearly white. The colors are generally lighter and the textures coarser than they are in the equivalent unmetamorphosed dolomites. Smaller but nevertheless prominent masses of rock consist of quartzite grading into interstratified quartzite and dolomite marble; thick layers of coarse-grained, nearly white calcite marble interlayered in dolomite marble; gray calcite marble; tactite; or hornfelsic and somewhat schistose rocks metamorphosed from shale and calcareous siltstone. All the lead-zinc-silver deposits here are in Devonian dolomite marble with interstratified quartzite (fig. 13).

Although contact metamorphism changed many lithologic characteristics and obliterated fossils, formations are recognizable by the sequence of sufficiently distinctive parts. Some formations are thinner than normal and others are represented by small parts of them isolated by faults and intrusive rocks. But the sequence in the area is corroborated by the geology in adjacent country.

The oldest formation of the Lippincott area shown on the map (pl. 2) is the Ely Springs dolomite of late Ordovician age. The lower boundary of the Ely Springs dolomite with the Eureka quartzite is well exposed on the ridge north of the area, where the stratigraphic sec-

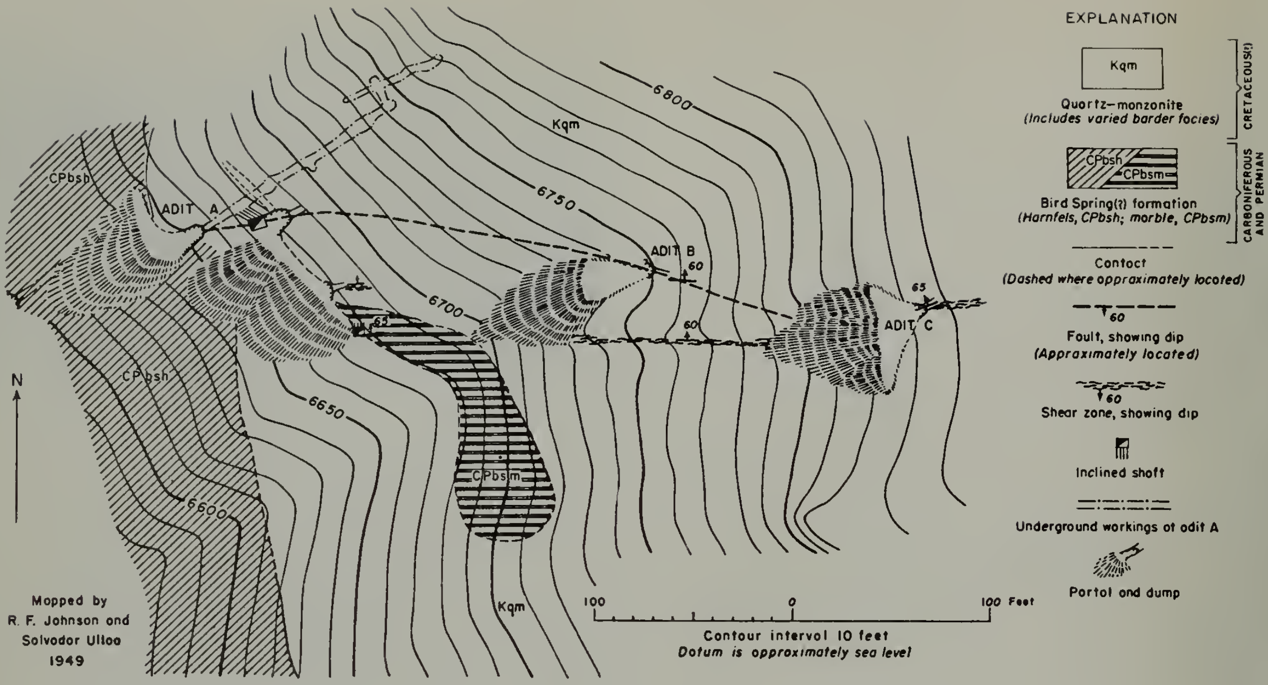


FIGURE 19. Geologic and topographic map of the Cerrusite mine area.

tion continues down through the Eureka quartzite and into Pogonip limestone at least as far as some distinctive brown-weathering siliceous beds midway in the formation. Two units of the Ely Springs dolomite are distinguished on the map. The lower unit is dark-gray dolomite and contains some nodules of dark chert. In sharp contrast the upper unit is very light gray dolomite and contains no chert. The thickness of the lower unit, where it is much less disturbed in a continuous stratigraphic section about 2½ miles north of Ubehebe Peak, is 380 feet, and the thickness of the upper unit is 560 feet, making the total thickness of the Ely Springs dolomite 940 feet.

The formation stratigraphically above the Ely Springs dolomite is the Hidden Valley dolomite, which in the standard sections contains Silurian fossils in the lower 435 feet and Early Devonian fossils in the zone that lies 50 and 65 feet below the top. The formation normally is about 1,365 feet thick. In the mine area, no fossils survived the metamorphism, which also altered the typical aspect by changing the color to lighter gray, and by destroying the usual nodules of chert. Despite the alteration there is still a mappable difference at the boundary between the Ely Springs dolomite and the Hidden Valley dolomite. The boundary is well exposed across the northern part of the area and in the central part of the eastern side, where it is much less definite. The middle part of the Hidden Valley dolomite, cropping out diagonally northwestward from the easternmost cabin and road junction, is coarse grained and nearly white. Some of the uppermost beds are finer grained and light gray, and some of the normally silty parts were altered to diopside and serpentine minerals, which on weathering make a rough and dark-brown surface. The upper contact with the Lost Burro formation is nearly vertical at the western end but is overturned to northeast dips along most of the exposure.

The Lost Burro formation, of Devonian age, contains all the lead-zinc-silver deposits in the Lippincott area. Most of the formation consists of dolomite and limestone, but it contains some calcareous sandstone and quartzite in the basal member and normally a little at the top (McAllister, 1952, pp. 18-19). The thickness at the type locality south of Lost Burro Gap is 1,525 feet, but in the Lippincott area, where the upper part is cut off by a lobe of a quartz-monzonite batholith or by a fault at the contact with the Tin Mountain limestone, the thickness is less than 1,400 feet. The dolomite was recrystallized to medium-grained marble, which is white or very light gray and weathers yellowish gray. Thick layers of coarse-grained calcite, which are conspicuous on the southwestern flank of the mine ridge, probably are recrystallized limestone beds; some irregular cross-cutting boundaries of the calcite masses and dark-brown stain from iron oxide may show that some of the calcite was hydrothermally redistributed.

Quartzite and sandy dolomite within the Lost Burro formation in the Lippincott area are conspicuous in the lowermost part of the formation, the basal siliceous unit here named the Lippincott member of the Lost Burro formation. As mapped (pl. 2), the member is about 200 feet thick from the contact of the underlying Hidden Valley dolomite to the top of the quartzite bed, about 25 feet southwest of the portal to the main workings. This does not include the separate quartzite beds interstratified with an equal or greater amount of dolomite toward the southwest, stratigraphically higher. The excluded quartzite beds, although lithologically groupable with the Lippincott member, appear to be somewhat lenticular and represent a transition to the uniform dolomite; the upper boundary of the transition is difficult to map on a large scale at precisely the same stratigraphic position. The upper boundary that was selected for the map is stratigraphically more consistent. Many details of the

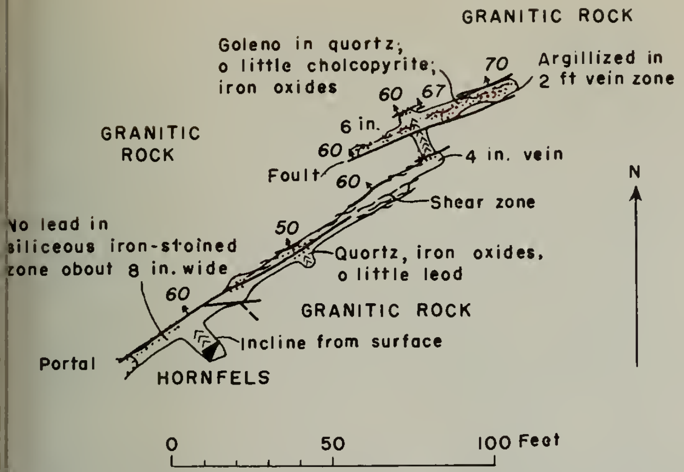


FIGURE 20. Geologic map of workings at adit A, Cerrusite mine.

sequence within the member were obscured by metamorphism and thorough fracturing. In general the more massive quartzite, which makes rough knobs on the minor spurs, is 50 feet thick and lies about 20 feet below the top of the member; the thin beds of quartzite, dolomite, or quartzitic dolomite weather to small fragments and make smoother slopes. Some of the siliceous material here, being in a contact-metamorphic zone, probably was hydrothermally redistributed and perhaps increased; but the Lippincott member persists throughout the region as a sandy or quartzitic dolomite wherever the base of the Lost Burro formation is exposed.

Beds of quartzite above the Lippincott member in the mine area range in thickness from less than a foot to about 10 feet in a dolomite marble zone about 100 feet thick. At most places there are five quartzite beds, at many places six beds, and where there are fewer or more beds the discrepancy perhaps coincides with structural

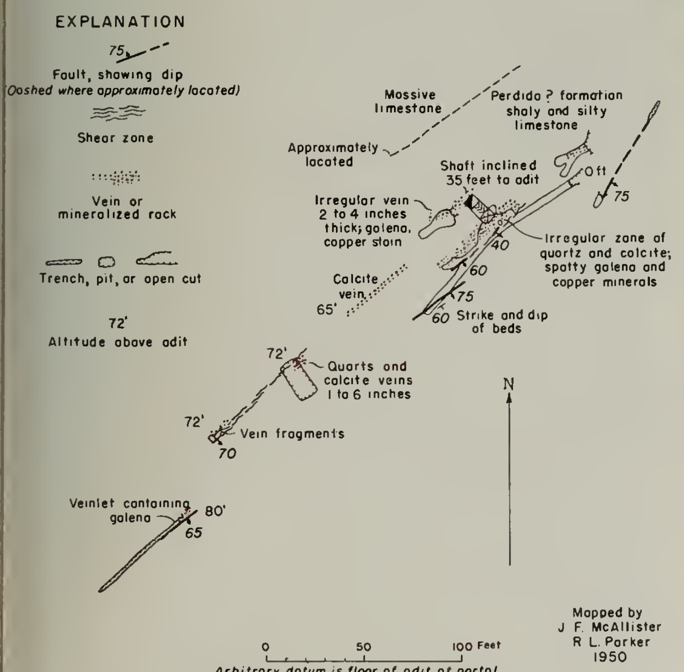


FIGURE 21. Geologic map of the Shirley Ann area.

complexity. The overlying dolomite marble for 300 or 400 feet is monotonously uniform, even the bedding having been effaced by metamorphism. Still higher in the sequence, on the southwestern flank of the mine ridge, slight differences in color and granularity, and calcite marble remain to show bedding; the shape and structure of some mottling suggest relicts of stromatoporoids, which are characteristic of a thick middle part of the Lost Burro formation. All the lead deposits of the area are in the lower part above the Lippincott member, and all that have been mined are in the transition zone of thin quartzite in dolomite marble.

Younger formations in the Lippincott area are not in stratigraphic continuity with the Lost Burro formation; fault zones and irregular masses of quartz-monzonite intervene so that identification of these well-metamorphosed formations is less reliable. Tin Mountain limestone, which in the normal sequence lies on the Lost Burro formation and has been called Mississippian, is faulted against the Lost Burro formation and is isolated in quartz-monzonite in the southwestern part of the area. The most conspicuous outcrop consists of medium light gray calcite marble, in which some of the thin bedding remains, associated with a foot or two of quartzite at the fault zone between it and the Lost Burro formation. The quartzite may be some of the persistently sandy or silty uppermost unit of the Lost Burro formation, which otherwise is unrepresented in the mapped area. In some outcrops southwestward, probable Tin Mountain limestone lies next to quartzite interstratified with limestone that is typical of metamorphosed sandy and cherty limestone of the overlying Perdido formation. The Tin Mountain limestone is normally about 475 feet thick but here no block of it in quartz-monzonite is more than 150 feet thick.

FIGURE 22. Lost Burro mine site, view west. East shaft is at dump farthest on the left. Foundations and part of frame of stamp mill are in center of view.

The Perdido formation is incompletely represented in small blocks, at most 200 feet thick, surrounded by quartz-monzonite. The thickness of the formation throughout the region has a wide range from 220 feet, 8 miles north of the Lippincott area, to about 600 feet at the type locality in the Quartz Spring area about 10 miles northeast of the Lippincott area. The Perdido formation is characterized also by variations in lithology; it includes limestone, bedded chert, siltstone, shale, and

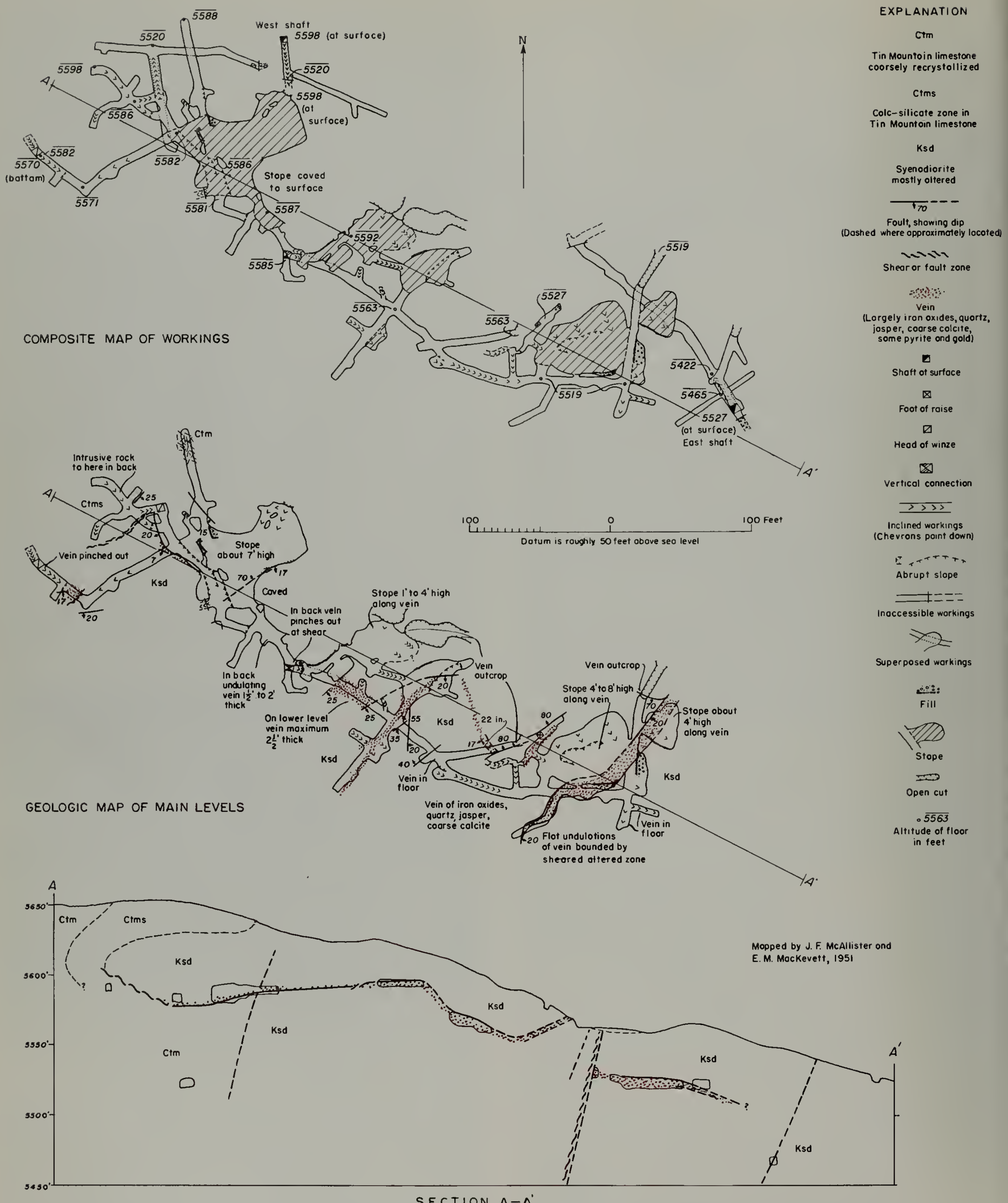


FIGURE 23. Composite map of workings, geologic map of main levels, and longitudinal section of the Lost Burro mine.

occasional conglomerate. In the Lippincott area the calcite marble of the Perdido contains streaks and layers of calc-silicate minerals and quartzite, which distinguish it from the Tin Mountain. The largest exposure is in contact with metamorphosed Rest Spring shale, which substantiates the identification of the Perdido.

Rest Spring shale underlies one area about 600 feet long and 100 feet wide, where it is in contact with the Perdido formation and quartz-monzonite. Here it includes hornfelsic and schistose rocks, which are olive gray and nearly black. Typical Pennsylvanian (?) Rest Spring shale, which normally is somewhat over 300 feet thick, consists of grayish black shale that weathers olive gray, siltstone, a little impure fine-grained sandstone that rarely is conglomeratic, and in some places, thin isolated beds of light-gray quartzite.

Alluvial deposits of two distinct ages locally veneer the Paleozoic and intrusive rocks in the Lippincott area. The older material as seen now on the surface is a residual concentration of the coarser parts of an ancient fanglomerate, making a bouldery cobble-gravel or in some places a boulder-gravel. It is a surficial lag gravel, which slumped or was reworked to the lower positions shown on the map. Fanglomerate that is a good example of the source material has the usual stratification and sorting of alluvial fan deposits on a lower ridge about a quarter of a mile west of the mine. Much more of the fanglomerate, which is sufficiently well consolidated to break off in large blocks, lies on ancient playa deposits in the foothills 2 miles northwest of the mine, and in the hills 6 to 7 miles northwest of the mine, where the fanglomerate is capped with basalt. The surficial lag gravel in the Lippincott area contains boulders of Eureka quartzite as much as 17 feet long, 10 feet wide, and 10 feet high, and many boulders whose maximum dimension is between 3 feet and 6 feet. Other constituents include gray dolomite and limestones (probably from many of the Paleozoic formations), quartz-monzonite, and other intrusive rocks. All the constituents may have been derived locally, under conditions similar to those in the present environment but long before the present topography was formed. The younger deposits are Recent alluvium in the valley bottoms and on a pediment, as in the southeastern corner and at the eastern margin of the mapped area.

Two unusual occurrences of polished and well-rounded pebbles are explained as being part of the older gravel. One occurrence is in the winze of the main workings, about 200 feet below the surface. Here the gravel, which is loosely held together by a waxy clay, was washed into a solution cavity at a shattered zone in dolomite of the Lost Burro formation. The polishing and excellent rounding of most siliceous pebbles show that the gravel is not slope rubble dumped into the cavity but is well-worked stream sediment. Similar polished and well-rounded pebbles are in a lithified calcareous matrix exposed on the surface 200 feet southeast of the shaft of the main workings. The pebbly layer, although as well lithified as the enclosing dolomite of the Lost Burro formation, cannot be an interstratified conglomeratic bed of Lost Burro age because many of the well-worn particles are of contact-metamorphic minerals (such as garnet), of hematite and other iron oxides, and possibly of altered intrusive rock. The pebbly rock is alined with an old tectonic breccia. Local erosion of the less resistant breccia provided a narrow trench-shaped trap for the finer gravel of the old alluvium, probably when the alluvium was first deposited. Similar and finer-grained stream material was washed through crevices into underground solution cavities, which it eventually filled.

The Paleozoic rocks now exposed in the southern and western parts of the mapped area were intruded by quartz-monzonite along the northeastern side of a great lobe from the batholith at Hunter Mountain. Within a mile north of this contact the same block of Paleozoic rocks was intruded by quartz-monzonite of the Ubehebe Peak mass, in such a way that the block abruptly narrows on the west side toward Saline Valley. The quartz-monzonite within the area is largely leucocratic and coarse grained; many feldspar grains are elongate and subparallel. At some places, especially near the border, it grades into aplitic, pegmatitic, and locally gneissic facies. The common quartz-monzonite consists of nearly equal quantities of orthoclase and plagioclase, less quartz, and a little hornblende. The volume percentage of minerals in a representative specimen from the ridge south of the area is: 41 percent orthoclase, 38 percent plagioclase, 16 percent quartz, 3 percent hornblende, and 2 percent accessory sphene and magnetite.

Dark, fine-grained dikes, rarely as much as a foot thick, crop out for short distances at a few places. The dikes cut the Lost Burro formation at small angles with the bedding about 200 feet north of the Confidence workings and 200 feet southeast of the Main Tunnel, and they cut across the quartz-monzonite near the southwestern edge of the mapped area, alined with tourmaline veins. Fineness of grain and alteration hinder determination of the original composition. Minor constituents include abundant pyrite in euhedral crystals commonly 0.05 to 0.1 mm in diameter, which on weathering accounts for the general brown stain of outcrops. Besides pyrite, tourmaline was added to at least one dike; another dike is continuous with a vein of tourmaline, barite, and limonite after pyrite. None of the dikes are associated with the lead deposits.

*Structure.* In the setting of regional structure, the Paleozoic rocks of the Lippincott area are part of a block that was caught between two large masses of quartz-monzonite. Much of the deformation of the block perhaps resulted from squeezing by forcible emplacement of the quartz-monzonite masses. The main part of the structure thus produced in the block is a tightly folded anticline, which—along with smaller folds on the northern side—plunges steeply west. A well-defined fault trending north across the block may have been started by the last part of this deformation, as the fault displaces the folds but is greatly obscured by metamorphism near the northern contact. Movement along the fault had the effect of displacing the beds on the western side about 500 feet toward the north. Some of the movement was sufficiently late to shear quartz-monzonite along the southward extension of the fault through the western part of the Lippincott area, but even the last movement took place before the topography acquired the present form.

Another fault follows much of the southwestern contact of the Paleozoic block and trends southeastward up

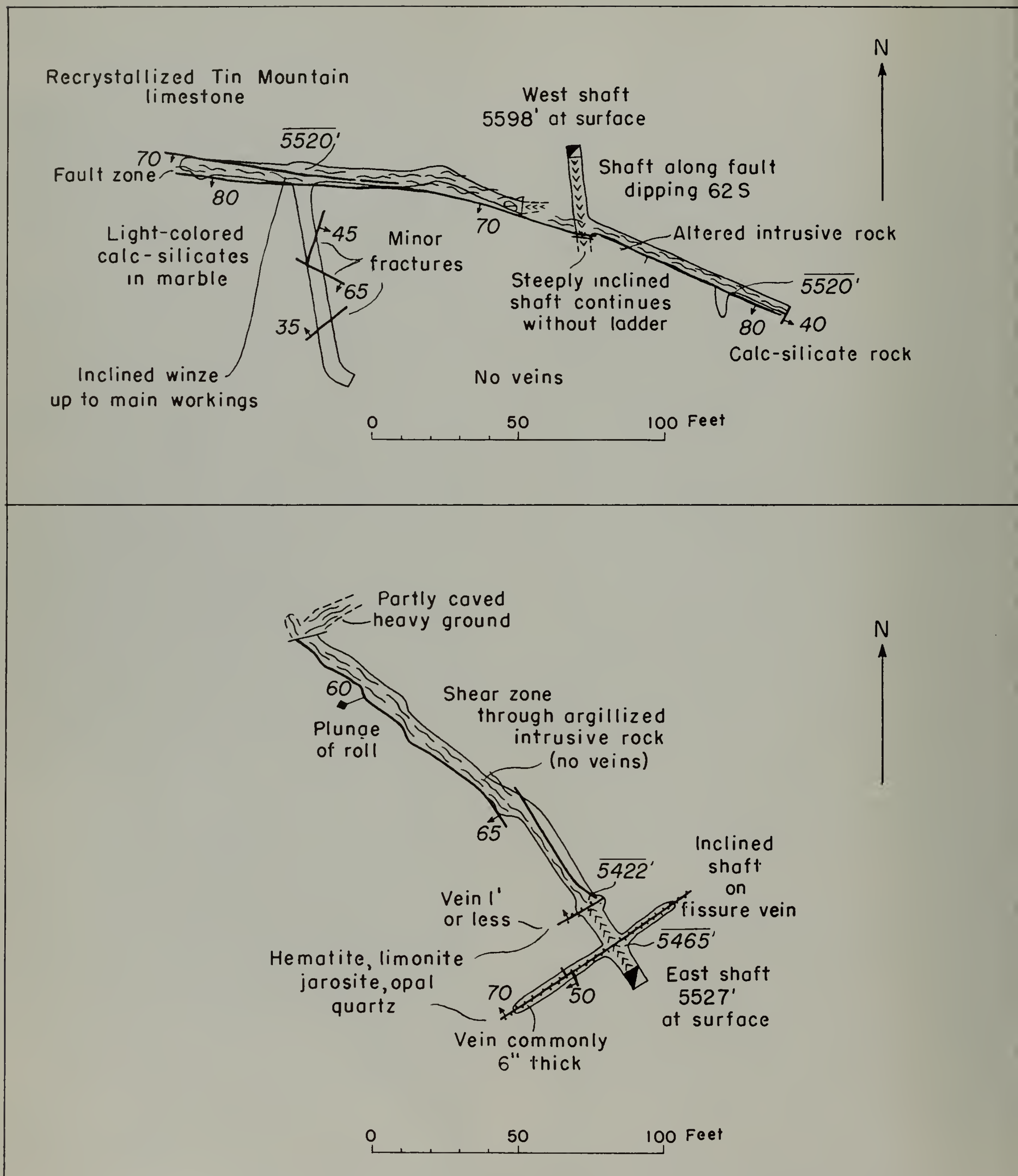


Figure 24. Geologic maps of some subsidiary workings, Lost Burro mine.

the canyon of the road to Saline Valley. It has a wide zone of gouge and breccia in the western part where the wedge is thinner between the quartz-monzonite masses. Southeastward, in the Lippincott area, the fault zone dissipates into a broad shear zone of indefinite boundaries, where much of the shearing was along beds. It did not abruptly displace the north-trending fault; the total effect was to warp the northern part relatively toward the southeast. This faulting involved quartz-monzonite and probably the old gravel but it made none of the existing details of topography. The southeast-trending fault is poorly expressed on the map of the area by a shear zone; it generally corresponds to the Lippincott member, which conceals much of the shearing along the beds. Some post-ore faults and loose breccias, clearly exposed in the mine workings, are roughly alined with the zone, and those that cut beds at acute angles curve out from bedding faults of the shear zone, in a horsetail pattern.

Within the Lippincott area the main structure of the Paleozoic rocks is a bend from an upright sedimentary sequence to an overturned sequence. Upright beds in the northern part of the area strike east and dip steeply south, but eastward the strike swings to southeast and the dip overturns to northeast so that here older beds lie on younger ones. The bending over of the beds makes part of an arch that looks like an anticline, but it places younger beds in the core, as in a syncline. The arch of older beds on top of younger ones, moreover, is not an inverted syncline, which must contain inverted sequences in both limbs; and it is not an overturned inverted syncline, which requires extreme rotation of both limbs, because here the limb of upright sequence has not rotated even once through a vertical position. The bend from upright beds to overturned beds is well exposed on the hillside south of the main drainage line. As seen here, the axis of overturning plunges east-southeast. Farther east a complementary plunging bend brings the overturned beds again to an upright sequence, but the curvature is broad and poorly expressed in the marble; eastward along the beds the strike swings nearer east again and the dip changes back to south in an upright sequence, as seen in the lower unit of the Ely Springs dolomite (northeastern margin of Pl. 2). The structure of overturning breaks into a fault midway across the area. Along the fault, which strikes east as far as the border of the area and dips about 70° S., the southern block shifted west in accordance with the overturn of the southern limb. The horizontal separation along the fault strike is well marked by the boundary between the upper and lower units of the Ely Springs dolomite, where it amounts to about 500 feet.

The overturned part of the whole structure occupies much of the Lippincott area and contains all the lead-zinc-silver ore deposits. Within the overturned sequence there are innumerable wrinkles that considered individually are inverted anticlines and inverted synclines. They stand out in brown-weathering calc-silicate parts of the Hidden Valley dolomite north of the main workings. Although these are not shown on the map, two other examples along the boundary between the Hidden Valley dolomite and the Lippincott member of the Lost Burro formation are shown by symbols for an inverted anticline and an inverted syncline to distinguish them from scallops made by the topographic trace of the more gently dipping part of the contact. Ore-bearing faults in the overturned sequence in general dip west and—as far as they could be traced—are short. Pod-shaped ore shoots in them plunge north. Other short premineral but seemingly barren faults strike nearly east and steeply dip either north or south, and where obvious they are somewhat silicified and stained brown. Clearly post-ore faults tend to strike parallel to the beds or swing out from bedding-plane faults at acute angles for short distances and dip somewhat less, in the same direction as the beds.

The ore-bearing part of the structure in the Lippincott area was probably produced through the deformation of the Paleozoic rocks by the intrusive force of quartz-monzonite masses. The ore-bearing fractures that strike northeast and dip northwest in the limb of overturned beds are properly oriented to be tension gashes normal to the axis of the overturn-bends. The bends may be accounted for by puckering at the place of most curvature from the north-trending beds southwest of the area to the west-trending beds northwest of the area, and the curvature was probably made by the shouldering aside by the quartz-monzonite mass southwest of the Lippincott area, partly against the Ubehebe Peak mass of quartz-monzonite north of the area. In another way the overturn-bends may be accounted for by the local pushing up and under from the southwest by a small protuberance from the quartz-monzonite mass. Either way, whether from a puckering in the large structure or from a local pushing up and under—but particularly if the latter—the quartz-monzonite contact is probably gentler, hence nearer the surface, under the mine area than it is at other places. The intrusive contacts generally dip 60° or more.

*Ore Deposits.* The mineral deposits in the Lippincott area have had exploitable quantities of lead, silver, and zinc minerals; noncommercial showings of copper, tungsten, and iron minerals; and some talc of unknown quality.

The silver-bearing lead-zinc deposits of the Lippincott area occur in poorly defined veins along minor faults and in irregular replacements of wall rock out from the veins. The original nature of the deposits has been greatly obscured by supergene alteration and limonitic staining, except where the galena is sufficiently massive or the deposit is silicified enough to obstruct weathering. Within the short vertical range of about 200 feet exposed by the mine workings, the oxidation of the sulfides has depended more on the local permeability of the enclosing material than on the nearness to the surface. Both galena and cerussite are in the outcrops and both are in the deepest exposures.

Galena, a little pyrite and sphalerite, and traces of chalcopyrite are the only metallic hypogene minerals that have been seen in the Lippincott mine. The original mineral assemblage included much more sphalerite and probably some molybdenite, as indicated by abundant supergene hemimorphite and some wulfenite. The local abundance of limonite, including pseudomorphs after pyrite, demonstrates that there was once considerable pyrite.

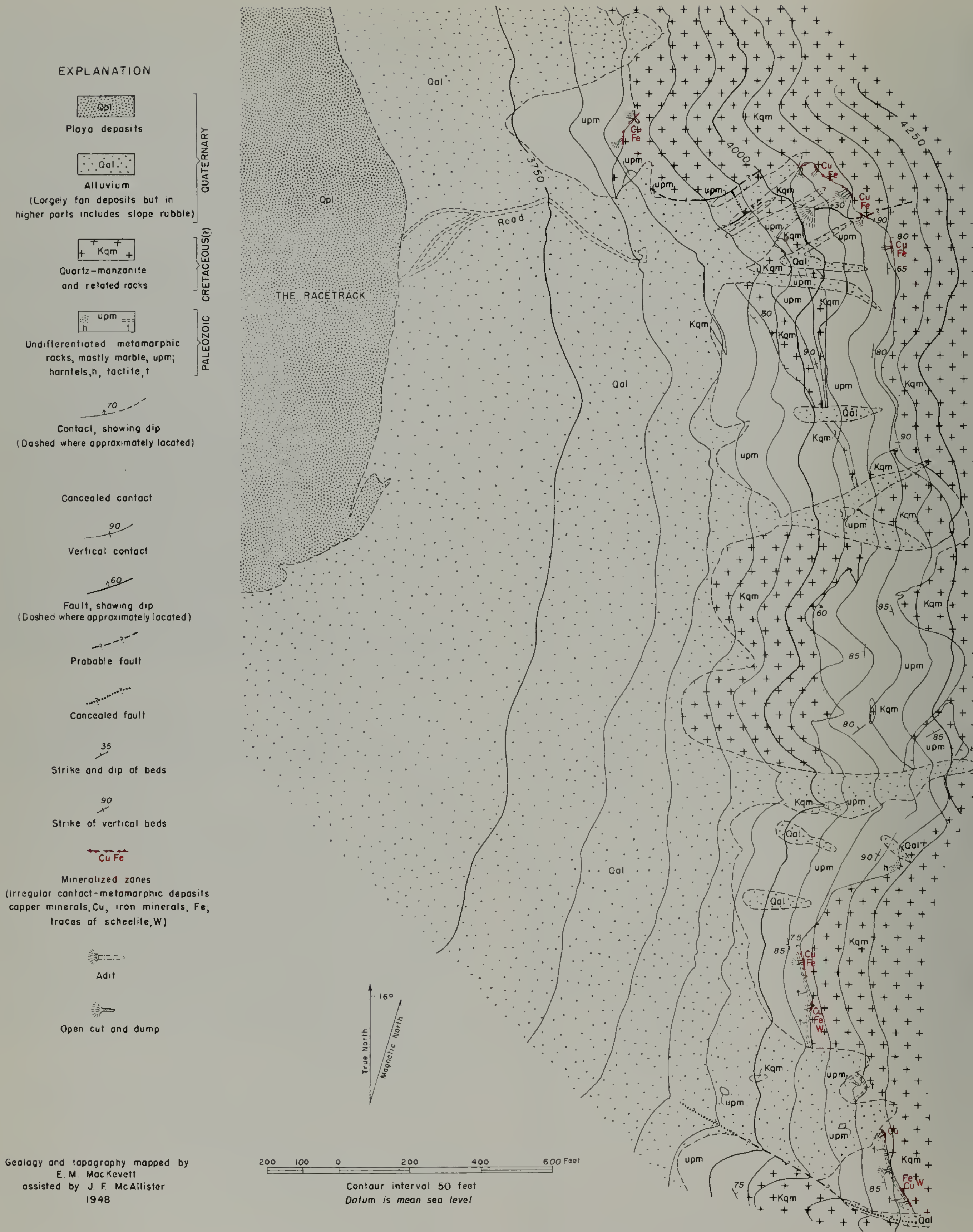


FIGURE 25. Geologic and topographic map of the Sally Ann area.

The galena is coarse-grained, occurring in bunches that facilitate profitable hand sorting, and it contains silver. A few fresh specimens have grains of galena that replace quartzite, some that are interstitial in quartz directly under drusy quartz in veinlets through quartzite, and some that replace massive vein calcite. Galena in the mine also directly replaces dolomite marble. It has not been determined what proportion of the galena replaces marble country rock, what proportion replaces fault material, or how much fills fractures. Minute specks of galena remain in some masses of cerussite that replace galena, and the specks where crowded impart to the cerussite a gray, dull metallic aspect.

Supergene lead minerals are much more conspicuous than the galena in the mine workings and in the mineralized outcrops. The most abundant supergene lead mineral is cerussite. Some masses of cerussite, which most clearly show the alteration from galena, contain particles of galena that range from large pieces having cubic cleavage to microscopic particles seen best in highly magnified polished sections. The appearance and the close association here with galena suggest anglesite rather than cerussite, but the mineral effervesces in cold dilute hydrochloric acid and fragments under the polarizing microscope have the strong birefringence of cerussite. Probable anglesite—dark-gray fine-grained aggregates that have a duller luster and do not effervesce in dilute acid—is confined to thin stringers along the cleavage of galena and to small patches in and around a little of the galena. Most of the cerussite is very light gray, nearly white or colorless, and forms solid masses or porous aggregates mixed with limonite. Clear euhedral crystals of cerussite, as much as 3 mm in diameter, protrude from some of the surfaces.

The other supergene lead mineral that occurs widely in these deposits is wulfenite. Although widespread, it occurs in noteworthy amounts at only a few places, as for example in the vertical part of the shaft in the main workings. The wulfenite invariably marks places of radioactivity. The more conspicuous crystals of wulfenite have the common thinly tabular habit and are as much as a centimeter in diameter but less than a millimeter thick, whereas others are elongate in fine-grained crusts. Very little of the wulfenite is anhedral, such as some in massive cerussite and stringers of quartz. Although it is one of the latest minerals, some wulfenite crystals are coated with drusy quartz.

Hemimorphite occurs as widely as the supergene lead minerals in the ore thus far seen and is practically the only zinc mineral present. The most conspicuous hemimorphite is in transparent euhedral crystals that project into cavities. The hemimorphite is one of the last supergene minerals to crystallize, occurring with and on the late drusy quartz, and some clear crystals contain inclusions of the spongy limonitic matrix.

A little unweathered sphalerite remains in the mine workings, especially where an earlier siliceous matrix has protected it from weathering. Some sphalerite in the Inspiration workings forms stringers, small clots, and disseminated grains replacing quartzite. This sphalerite ranges from very fine grained to coarse and from nearly olive black to very light. It is accompanied by a little pyrite and less chalcopyrite.

Limonite is abundant, especially in the main workings of the mine; it is particularly conspicuous in the short drift referred to on the map as the "C" level. Much less is exposed in the Confidence and Addison workings. Although limonite occurs in the ore zone, an abundance of it does not indicate high-grade supergene ore; some limonite, as in zones of brown-stained calcite about 375 feet and farther from the portal of the main workings, is not associated with lead and zinc minerals.

The gangue, apart from dolomite wall rock mined with the ore, is mostly siliceous. Some of the silica is in brown jaspery masses and in gray chalcedony veins, and some is in moderately fine grained clear quartz. Drusy quartz, which continued to crystallize after some of the supergene lead minerals, is one of the latest minerals. No massive quartz vein filling has yet been seen here contemporaneous with the galena, but polished sections of the ore show some galena in quartz veinlets. Fine-grained quartz aggregates mined with some of the ore are quartzite from thin beds in the dolomite country rock.

A little of the gangue is coarse-grained calcite, which was deposited at least in some places (as in the surface workings near the shaft of the main workings) sufficiently early to be replaced by galena and pyrite. The calcite, which effervesces readily in dilute hydrochloric acid, is medium gray to very light gray and weathers brownish, perhaps indicating that it contains iron although it is not siderite. Some of it, as at the above locality and in the drift of the Addison workings, fluoresces light red under ultra-violet light. The fluorescent part of the calcite is in irregular patches or bands, either sharply outlined or serrate from intergrowth. Some druses in the Taylor shaft consist of rhombohedrons of dolomite. Other cavity linings, noteworthy in the first short drift from the Main Tunnel, consist of aragonite in slender white or colorless crystals as much as a centimeter long. In fragments under the microscope the biaxial negative interference figure and the indices of refraction distinguish it from calcite. Some of the aragonite crystals are needlelike and distinctive, but others that are broader can be mistaken offhand for hemimorphite unless confirmed by effervescence in acid. Aragonite in the Addison workings occurs near hemimorphite. The gangue contains also some clots of finely granular gypsum, a little clay, some light green and nearly white micaceous flakes, and some remnants of antigorite and chrysotile.

The relative amounts of lead, zinc, and silver in the ore at different places in the Lippincott mine workings have not been systematically investigated, but the results from scattered sampling by the U. S. Geological Survey suggest that the parts richest in lead are not the richest in zinc, and that the variance is partly, although not entirely, the result of supergene redistribution. Samples from the Addison workings have in general about twice as much lead as zinc except in the lowest exposures west of the ore shoot, where the content of zinc remains high and the lead decreases to one-third or one-fourth of the zinc content. This part, along the ore-controlling fault, is down the dip from the plunging ore shoot, consequently the zinc can be explained by supergene migration. In the Johnson tunnel, according to only four samples along the 60-foot exposure of vein, abundant zinc predominates over the lead near the portal, but

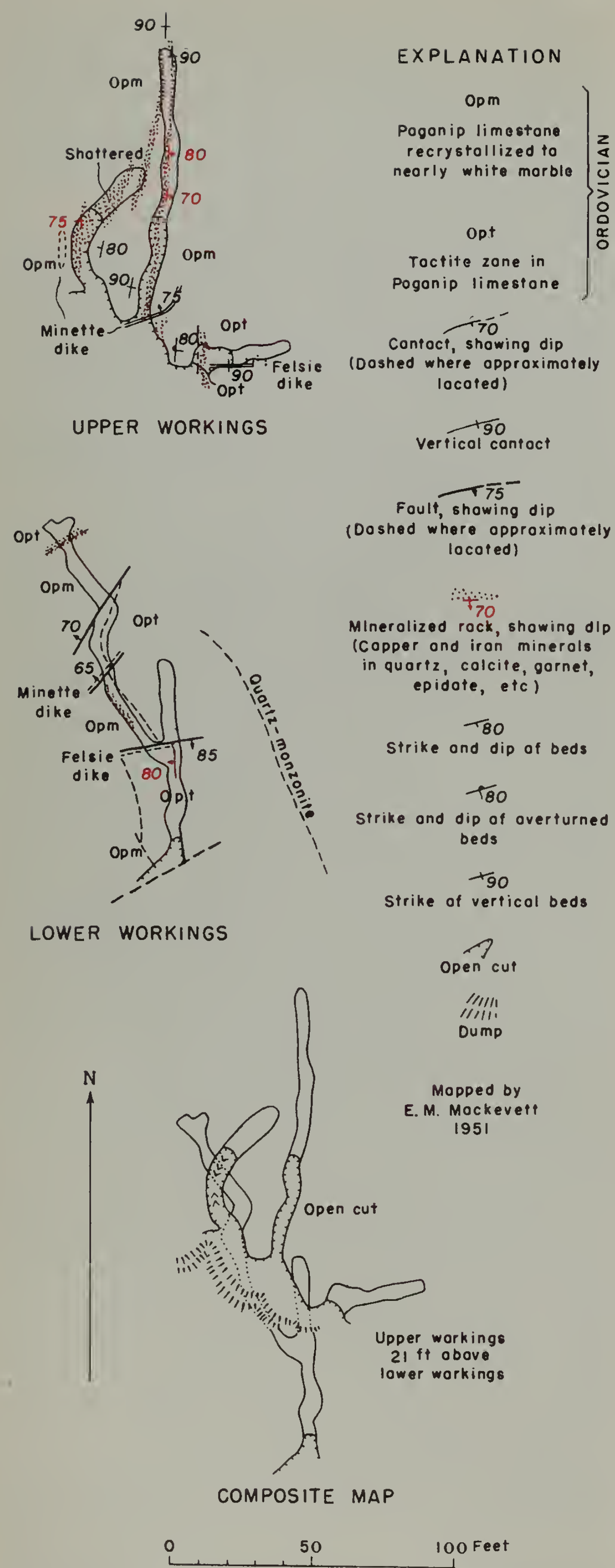


FIGURE 26. Composite and geologic maps of the Copper Bell mine.

the quantity of zinc abruptly decreases inward and the quantity of lead increases. In the next ore shoot farther northwest, extending from prospect pits at the surface down to the Confidence No. 2 tunnel, three samples are consistently high in zinc and low in lead. The content of silver in the Addison samples increases with the increase in lead and shows no consistent change in relation to the content of zinc and it shows less convincingly a similar trend in the Confidence No. 2 stope. In the Johnson tunnel the silver content decreases erraticallly with the increase in lead and increases consistently with the increase of zinc toward the portal. According to Norman and Stewart (1951, p. 74), "Lippincott states that the relationship of high silver to high zinc content is typical of the ore."

The principal structural control of the Lippincott lead-zinc-silver ore deposits is a set of short mainly west-dipping faults in the stratigraphically lower part of the Lost Burro formation, but above the basal member. The ore-bearing faults localized pods of ore plunging north at places where the faults roll, as if along tension gashes. The pods, like the ore deposits in general, seem to be replacements along faults rather than thick fillings of open fissures. Some of the wider parts of ore shoots are where the replacements extend out along favored beds. All the deposits that have been worked in this mine area occur where the faults cross dolomite marble interstratified with a few thin beds of quartzite closely above the highly siliceous Lippincott member of the Lost Burro formation.

The ore-controlling fault in the Addison workings (fig. 14) strikes about N. 15° E. and dips about 70° W. in the upper part of the incline near the surface, but northward down the incline it rolls over to N. 60° E., 30° W. at the bottom. As exposed in the lower drift, toward the southwest, the same lead- and zinc-bearing fault in general strikes N. 45° E. and dips 50° W. The fault is normal, and the offset possibly is about 15 feet southwestward on the northwest side. The mineral ore shoot along the fault plunges down the incline about 40°, N. 7° W. The width of the vein along the back of the ore shoot ranges from about 3 inches to about 15 inches, and perhaps it widened to 2 or 3 feet in the mined-out parts. Chip samples across it have a persistently high content of lead and erratic quantities of zinc. A representative sample 19 inches wide across the 14-inch vein at the foot of the incline, assayed 28.12 percent lead, 8.25 percent zinc, and 13.22 ounces of silver per ton.* Away from the ore shoot, two samples spaced widely along the southwestern drift indicate low-grade lead and about three times more zinc than lead. As this part of the vein is down dip from the upper part of the plunging shoot, the high proportion of zinc relative to lead suggests that supergene zinc enriched the vein below the original ore shoot, and that the extension of the hypogene ore body should be sought not down dip from the drift but at the foot of the incline.

The vein in the Confidence No. 1 workings (fig. 15), where it is exposed for 60 feet along the Johnson Tunnel, was controlled by a premineral fault that strikes about N. 55° E. and dips 55° to 65° W. The fault is normal, for beds dipping steeply eastward are offset about 7 feet relatively toward the west in the north or

* Assays are by D. L. Skinner, U. S. Geological Survey, 1950.

hanging wall. The vein along the fault is generally 3 to 5 inches thick but narrows to a stringer at some places and widens at other places to lenses as much as 2 feet thick. About 20 feet from the portal a branch vein dipping 60° E. strikes into the southern wall of the workings, and it probably is the vein exposed by shallow prospects on the hillside south of the portal. The adit vein 60 feet from the portal is cut off by a northwest-striking postmineral fault, which defines the eastern side of a brecciated zone 35 feet wide. The breccia is loose, and near the faulted vein it contains a few fragments of vein material. Beyond the breccia the vein is not exposed again in workings about 135 feet long, and the faulted end probably is not nearby. An ore shoot in the vein, mined from the Taylor inclined shaft, plunges roughly 40°, N. 10° W. and is alined in a general way with a thicker part of the vein in the adit about 40 feet above it, and with exposures in prospects at the surface. A parallel trend of ore pockets was followed down much of the inclined shaft, and the largest pocket was stoped about 15 feet west of the lower end.

The ore-controlling fault in the Confidence No. 2 workings strikes about N. 10° E. and dips 75° W. near the portal. The dip diminishes gradually to 55° W. near the southern end of the workings, 115 feet from the portal. A replacement deposit along the fault, containing a little sphalerite and traces of galena, extends only about 40 feet along the exposed length of 110 feet. This more favorable part was explored by sinking an inclined winze 45 feet long, and by drifting short distances midway and at the bottom of the winze, but no ore shoot was found. A small, irregular ore shoot, about 30 feet from the portal, was stoped to the surface. The upper part of the stope is vertical for 13 feet, and the lower part plunges about 35°, N. 10° W. along the premineral fault where it lies N. 5° E., 70° W. Three U. S. Geological Survey samples that were chipped across the vein in the wall of the stope at the bottom, halfway up, and near the top, have from 5 to 16 times more zinc than lead.

The vein in the Confidence No. 2 workings possibly is the western segment faulted from the vein in the Johnson Tunnel. If so, the horizontal separation along the fault strike at the Johnson Tunnel level is about 220 feet. The proportion of dip-slip to strike-slip movement on the post-ore fault is not known. If the movement was down the dip of the fault, which averages 60° NE., the ore in the Confidence No. 2 workings could be the root of the ore shoot in the Taylor shaft; but if the movement was along the strike of the fault, the Confidence No. 2 ore shoot is not part of the Taylor shoot (originally they would thus have been about 100 feet apart along the strike of the vein), and the faulted part of the Taylor shoot, if it extended down sufficiently to be cut by the fault, would be at considerable depth far north of the Confidence No. 2 portal.

Two minor faults control the ore in the main workings (figs. 16 and 17). One is followed by the Main Tunnel to where the fault is cut off by a cross fault 130 feet from the portal, and the other ore-controlling fault, which is almost normal to the first, is exposed by the northwest drift on the tunnel or "A" level, also by part of the shaft, some intermediate workings, and by an open cut near the shaft collar. The Main Tunnel fault has vein minerals along it for about 35 feet, starting 50 feet from the portal. A stope along the first 10 feet of the vein, from about 8 feet above the floor to slightly below the floor, shows that a pod of ore plunged north, where the vein strikes N. 40° E. and dips 40° W. The vein pinches out southwestward as the fault steepens to 55° W. and curves to a strike of N. 65° E. The offset along the fault at the small stope is about 10 feet southwest on the north side, but beyond a fault that lies N. 45° W., 80° S. in the hanging wall the offset is about 3 feet.

A premineral fault associated with the main ore deposits is well exposed in the northwest drift, where the fault strikes N. 30° W. and dips 65° to 75° W.; it steepens southeastward to the areas around the shaft and the "C" level, where it is essentially vertical or locally rotates from 80° to 85° E. Ore shoots along the fault and in adjacent rock have irregular outlines and a spotty arrangement; but the ore zone as a whole plunges about 70°, N. 20° W. from the outcrop down to the "A" level, an inclined distance of about 160 feet, and more nearly north below the "A" level. Patches and veinlets of galena and cerussite remain in the walls of the workings from the open cut to the bottom of the winze, which early in 1951 was about 200 feet below the surface. Wulfenite, which is pale yellowish orange and mostly fine grained, is as widely distributed as the other lead minerals, and the wulfenite locally (for example near the foot of the vertical part of the shaft) is concentrated in loose aggregates. The ore-controlling structure is least clear where the larger pockets of ore were mined, largely because of masking by limonitic and other supergene alteration. There is some indication that the ore minerals replaced shattered rock, possibly favoring particular beds for short distances out from the faults. The main pockets of ore were mined in the "B" workings between the "A" level and the "C" level, which is 90 feet higher, and mostly within 50 feet of the "A" level. Apart from the main ore zone a pod of ore in the vein along the same fault was mined in the northwest drift about 75 feet from the intersection with the Main Tunnel. The vein here is cut off by a barren fault N. 55° W., 75° E. that continues across the Main Tunnel and southeastward through the short angular working northeast of the winze.

Another barren fault zone is the most conspicuous part of the structure in the mine. The north side of the 30-foot shattered zone is 140 feet from the portal. Underground the shattered rock and breccia are loose, like the fault breccia in the Johnson Tunnel, but where it crops out north of the shaft the breccia is lithified to a coherent mass. Several faults, limonitic zones, and zones of calcite-lined vugs in coarse dolomite marble, but no ore minerals, were cut by the southwestward extension of the Main Tunnel for 380 feet beyond the vein in the drift. Near the end is a conspicuous cavity filling of brown silt and clay, similar to some of the cavity filling at the bottom of the winze.

The area has been thoroughly prospected. Prospects showing lead minerals are limited to the part of the Lost Burro formation that is on the northeastern flank of the mine ridge, between the mine workings and the crest. Most of them are around the Confidence workings and southwest of the Addison workings. Although a prospect southwest of the Confidence workings and at the top of the ridge contains lead, none of the prospects southwest of the entire ridge seem to have lead, zinc, or silver, and the conspicuous zones of brown-stained calcite are barren. Thus the most favorable places for the occurrence of new pods of ore in the area probably are down the trends of the mined ore shoots in the Addison, Confidence No. 1, and the Main workings, rather than at any of the scattered prospects.

Apart from the lead-zinc-silver deposits, the copper and iron minerals in the Lippincott map area are concentrated in isolated masses of tactite at intrusive contacts. The most conspicuous features of these deposits are the masses of limonite, hematite, and magnetite, in tactite that consists mostly of dark garnet. The iron oxide minerals in some parts of the tactite are associated with brown jasper, quartz, clay, and antigorite. Cores of pyrite remain in some of the massive limonite. The largest mass of tactite containing much iron oxide and some copper, in the Lead Giant (Contact) claim about 150 feet south of the road to Saline Valley, is 200 feet long and as much as 30 feet wide. Another mass, which is at a short prospect adit about 1,400 feet farther south, is 100 feet long and at most 20 feet wide. Supergene copper minerals are more conspicuous in tactite at the Spanish Tunnel in the southeastern corner of the area. Here the dark garnet is associated with much idocrase and epidote, which are partly in an aplitic-pegmatitic border facies of the quartz-monzonite. Nearby there are some erratic masses of radially fibrous tremolite and of scapolite. The few chip samples (U. S. Geological Survey) that were collected at several widely spaced deposits contain no gold, silver, lead, or zinc, and in general less than 1 percent copper.

Only a few grains of scheelite were found by means of an ultraviolet lamp, 400 feet southwest of the road at the southernmost cabins in the Lippincott area. The scheelite is not in the dark iron-bearing tactite, which is at the intrusive contact, but in light-colored calc-silicate rock derived from a siliceous layer in marble, about 300 feet from the exposed contact.

Closely associated with the tactite, and in quartz-monzonite farther from the intrusive contact, there are several long, thin tourmaline veins. The tourmaline vein south of the tunnel was traced for 350 feet. In it the nearly black, massive, fine-grained tourmaline is shown by a thin section to be a felty aggregate of grains commonly about 0.02 mm thick and 0.15 mm long, and pleochroic from grayish green to nearly colorless. Tourmaline replaces calcite and brecciated quartz, and it is cut by stringers of late calcite. Barite and iron oxides occur in tourmaline veins in the southwestern part of the area.

Other veins in the quartz-monzonite in the southwestern part of the area consist of quartz and limonite, and are as much as 200 feet long. A chip sample (U. S. Geological Survey) of a limonitic quartz vein contains no gold, silver, copper, lead, nor zinc.

Some talc is exposed in pits and trenches on the Homestake claim of R. B. Walls, a few hundred feet southwest of the junction of the mine road with the road to Saline Valley. The talc is motley and streaky bluish gray, and much of it is well shattered. Whether it is steatite or other commercial grade is not known. The Homestake talc is a spotty hydrothermal alteration of the dark, cherty dolomite in the lower unit of the Ely Springs dolomite.

#### Cerrusite Mine

The Cerrusite mine (figs. 18 and 19) is on the southwestern slope of the Nelson Range at an altitude of approximately 6,700 feet, north of Lee Flat (see fig. 2), and is in sec. 7, T. 16 S., R. 40 E. (projected). It is about 50 miles by road from Lone Pine: 35 miles of the road is paved highway out from Lone Pine and 15 miles is unsurfaced. There is no water supply nearby; the nearest adequate source is at Keeler, about 35 miles by road.

The Cerrusite mine was owned by W. A. Reid in 1938, when development was reported to consist of three tunnels 200 feet long at 100-foot intervals, and when the ore was worth \$12 to \$25 per ton, chiefly in silver (Tucker and Sampson, 1938, p. 434). Mrs. Agnes Reid in 1948 leased the mine to C. W. James (Norman and Stewart, 1951, p. 172).

The geologic map of the small main workings (fig. 20) was made with the help of E. M. MacKevett in 1948, and the topographic and geologic map of the area around the workings (fig. 19) was made in 1949 by R. F. Johnson and Salvador Ulloa. Three main adits, called adits A, B, and C in this report, are spaced at vertical intervals of 100 feet and 80 feet and have a total length of nearly 400 feet. Adit A is 116 feet long, to a winze at the end. The winze is steeply inclined for about 35 feet, and 55 feet of drifts extend out from it at about 20 feet down from the adit. A 35-foot adit is about 50 feet lower than adit A, and several small workings are about 30 feet higher than adit A. Although traces of lead minerals occur in adits B and C, ore was found only in the workings connected with adit A.

The lead ore deposit is in veins in sheared, sericitized granitic rock near the contact with hornfels and marble, but a short segment of thin barren vein extends into the hornfels near the portal of adit A. The hornfels is a metamorphosed siltstone or silty shale, which probably was one of the dark greenish gray shaly beds interstratified with limestone in the Bird Spring(?) formation of Pennsylvanian and Permian age. The granitic rock shows considerable variation in this border zone of a batholith, ranging from rather dark quartz-monzonite to aplite and pegmatite. A common variety is medium-grained biotite-hornblende quartz-monzonite, which contains a greater proportion of mafic minerals than the bulk of the quartz-monzonite in the batholith. Some of the pegmatite consists of nearly equal proportions of pink orthoclase and hornblende.

The ore-bearing veins were controlled by minor fault zones, which strike between N. 70° E. and nearly east and in general dip 60° N. The fault zones are not sharply defined, and in detail they appear to consist of overlapping and branching fractures. The mineral deposits therefore are discontinuous, and where widest they are somewhat like a lode. As the veins or other indications of the fault zones do not crop out through the slope rubble between the workings, it is not known whether or not the zones are actually continuous up the hillside from adit A past adit B to adit C. A continuous zone requires a slight curvature to offset the part at adit C somewhat southeastward from the part in adit A. A shear zone that strikes east and dips 60° N. about 35 feet south of adit B may extend through the area and after curving somewhat northeastward may shear off the vein at adit C.

The ore consists of coarse-grained galena, which contains some silver, in a gangue of quartz. Some of the galena, as seen in adit C, has been altered to coarse-grained cerussite. There is a little chalcopyrite and copper stain, and considerably more limonite, which came probably from oxidized pyrite. Some of the quartz and the quartz-monzonite wall rock were sericitized. Assays (U. S. Geological Survey) of a few samples of the vein in adit A contain less than 1 percent lead except at the winze and in the drift below, where galena is obvious and the lead content is high. Even the samples with the most lead have only a few ounces of silver, traces of gold, and no zinc. The only favorable place for exploration seems to be around the lower drift of adit A, possibly downward and toward the east.

Traces of the lead mineralization occur west and southeast of the Cerrusite mine, but farther southeast and north of the mine copper minerals rather than lead minerals show in the prospects and small mines. About a quarter of a mile west of the Cerrusite mine some galena in iron-stained quartz was seen on a dump at the 15-foot shaft in the Flat Top claim. In another prospect, where no claim notice was found, 0.65 mile straight S. 25 E. from the Cerrusite mine, an open cut about 25 feet long through metamorphosed shale and marble crosses a vein along a fault. The vein, which lies N. 85 W., 80 N. across beds of the Bird Spring(?) formation at about N. 5 W., 85 N. W., consists of quartz and calcite and is about a foot thick. In the hanging wall of the vein there is a pod about 4 inches thick of coarse-grained galena.

#### Shirley Ann (Eureka?) Deposit

Small mine workings in the Shirley Ann claim, about 1,000 feet due southwest of Big Dodd Spring, are about 4,200 feet above sea level, and in sec. 1, T. 16 S., R. 40 E. (projected). Access to the property is by rough trail, either from the end of the road at the Lippincott mine, which is between 4 and 5 miles north by trail, or from the Saline Valley road in the lower part of Grapevine Canyon, which is about 2½ miles south by trail.

The workings are old and unquestionably have been mined under other names, but which of the old mining properties near the Dodd Springs it is cannot be determined by old claim notices, which are gone, and can be only surmised from descriptions of the localities, which are inadequately defined for the records. The only claim notice seen in 1950 was undated and stated merely that the Shirley Ann mining claim was owned by H. P. Gower. According to Inyo County records the Shirley Ann claim 6 miles south of The Racetrack was located by Earle Carr, Jr., in 1940. Among the descriptions of old claims near "Dodd's Springs" that are in an early report (Aubury, 1902, p. 246), the description of the Eureka claim most nearly suits the Shirley Ann claim. No other mining property there in 1902 had underground workings, whereas the Eureka claim was said to have an 80-foot shaft and 100 feet of drifts on the vein. Furthermore, only the Eureka claim was reported to have galena occurring with the malachite.

The Shirley Ann workings include a southwest-trending adit 100 feet long. Up from the adit a shaft is steeply inclined through a vertical distance of 35 feet to the surface (fig. 21). Tapering into the shaft from the adit is a small stope about 5 feet wide and at most 25 feet long. A short drift on the adit level continues from the stope for about 20 feet southwestward. Two short adits lie north and south of the main portal, and an irregular working southwest of the shaft collar extends underground about 20 feet. There are several pits and trenches southwest and northeast of the main workings.

The mineral deposit is in shaly and silty limestone metamorphosed by quartz-monzonite, which is exposed several hundred feet west of the deposit, and by a dioritic facies exposed somewhat farther east of the deposit. The metamorphic rocks, which may be part of the Perdido formation, are in a septum that pinches out southward between the bulk of a batholith on the east and an extensive lobelike exposure of the batholith on the west. The septum is well metamorphosed and complexly faulted.

The mineral deposits in the Shirley Ann area were probably controlled by faults more or less parallel to the beds, and in some places the deposits were shattered by later movement along faults. The deposits are local, and irregular in detail of outline as well as in distribution. The largest deposit, which is the only one likely to contain lead or copper ore, is exposed for 100 feet in the adit (and up the shaft to the surface). It probably continues at least as a mineralized zone 40 feet farther northeastward to the portal of the small adit. Southwestward from the shaft the deposit was followed by a shallow working for about 10 feet, but the mineralized zone above the workings crops out for about 50 feet. Short exposures of poorly alined thin veins of calcite or calcite and quartz continue southwestward for about 250 feet from the shaft. Of these, a veinlet in the southwesternmost trench contains a little galena.

The main deposit differs from the lead deposits at the larger mines in the quadrangle by the greater abundance of copper minerals with the lead minerals, and by the scarcity of zinc minerals. Early mining here probably was for the copper. Bunches of galena and cerussite occur in quartz and calcite gangue. The galena is replaced by cerussite, by some covellite along cleavages and around borders, and probably by a little anglesite; the greatly predominant replacement of the galena is by cerussite. Some masses of cerussite seen in polished section contain specks of galena that diminish in concentration away from the cores of solid galena, and the entire masses are outlined within the quartz gangue by shapes that could be relicts of the galena crystals. Cerussite in stringers also cuts across quartz; some is interstitial in microbreccia of quartz; and some is cut in turn by a little wulfenite. Considerable cerussite makes coarse aggregates showing excellent cleavage. Covellite, as well as replacing some galena, forms some large grains, and some is intergrown with chalcocite. Malachite, other supergene copper minerals, hematite, and limonite occur widely.

The smallness of the deposit and the isolation in rough country discourage further mining. The probability, however, of a downward continuation of the shoot of lead and copper minerals, plunging perhaps about 55°, S. 80° W. from the foot of the shaft, seems good.

## Gold

### Lost Burro Mine

The Lost Burro gold mine, in the northeastern corner of the Ubehebe Peak quadrangle (see fig. 2), is near the top of the eastern side of the mountains between Racetrack Valley and Hidden Valley. The mine is in sec. 16, T. 14 S., R. 41 E. (projected). Leading from the mine, a poor road 1.2 miles long joins the scraped but otherwise unimproved road in Hidden Valley, from where it is about 23 miles to the paved road at Ubehebe Craters, Death Valley, and about 135 miles to the nearest railroad, at Keeler.

The mine area that was mapped is about 1,000 feet long and 700 feet wide, extending well beyond the underground workings. The extent of the area is unrelated to boundaries of mining property. The plane-table map of the mine area, made with the assistance of E. M. MacKevett in 1951 (pl. 3) was initially oriented by compass and the altitude of the first station was taken by aneroid. Comparison with the subsequent topographic map of the quadrangle suggests that the datum of the mine-area map is roughly 50 feet above sea level. The mine workings were mapped, with the assistance of E. M. MacKevett in 1951, by tape, clinometer, and peep-sight alidade on a small plane table. The orientation and altitudes of the mine maps (figs. 23 and 24) were adjusted to coincide with the surface map of the mine area.

Geology is plotted only on level parts of the mine but is supplemented at intervening parts by notations on the map and by a longitudinal section.

*History and Production.* The oldest claim notice at the mine in 1946 was dated April 20, 1907, and it listed as locators W. D. Blackmer, W. B. Morris, C. N. Gardner, A. McCormick, and D. F. Shively. The earliest published account of the mine (Waring and Huguenin, 1919, pp. 81-82) describes the workings in 1916 as consisting of several short tunnels driven along a vein and refers to a mill under construction in 1917. Water was piped about 8 miles from Burro Spring. About that time the Lost Burro Mining Company, of Los Angeles, was reported to have sold the mine to the Montana-Tonopah Mines Company (Waring and Huguenin, 1919, p. 82). The owner in 1949, Mr. W. C. Thompson of Caliente, Calif., said that the Montana-Tonopah Company leased the mine from Andy McCormick from 1906 to 1912, after which Andy McCormick and Phil Day mined $85,000 in gold (Thompson, oral communication, 1949). McCormick by himself continued to mine at least as late as 1938, sporadically shipping small lots of 2-ounce gold ore (McCormick, oral communication, 1938). The property in 1951 was owned by W. C. Thompson (Norman and Stewart, 1951, p. 155).

The Lost Burro mine from 1935 to 1942, inclusive, intermittently produced 255 ounces of gold, which is the only production listed in the annual records in the San Francisco office of the Metal Economics Branch, U. S. Bureau of Mines.* But according to Mr. Thompson, and the indications in the mine, the production was much greater. The following rough estimate of a possible order of magnitude of production may therefore be justifiable. Using the round numbers of 10,000 square feet for the area of stopes shown on the mine map (fig. 23) and of 3 feet for the average thickness of the mined vein gives 30,000 cubic feet of mined ore. The specific gravity of a specimen from the vein, composed mainly of quartz and iron oxides in jasper but containing traces of visible gold, is about 3.0, which makes 187 pounds per cubic foot of vein. Thus 30,000 cubic feet contains about 2,800 tons, which, at 1 ounce of gold per ton, contains 2,800 ounces of gold worth at that time $58,000. At 2 ounces per ton, as reported by Mr. McCormick, the yield is 5,600 ounces of gold then worth $116,000. Production from the mine therefore may have been worth on the order of $100,000.

*Mine Workings.* The total length of mapped workings is about 1,650 feet, and the total area of stopes is about 9,800 square feet. Some parts of the mine are unsafe, such as the large west stope where timbers had buckled and part of the stope had caved from the surface, and the inclined stope opening to the surface in the central part of the mine. A few steep workings lacked ladders, as in the west shaft below the 5,520 drift, where the shaft was too steep and too deep for reasonably safe access by rope.

The accessible workings are under an area of about 2 acres, within a maximum vertical distance of 175 feet, but most of the workings are about 50 feet below the surface, rarely as much as 100 feet, and at most 130 feet below the surface. The main workings include three groups of low somewhat flat-lying stopes and accessible workings that connect all the stopes and lead to the surface through two adits at altitudes of 5,563 and 5,519 feet. The two higher stopes have partly caved openings to the surface. The main workings have no connection to workings at the west shaft, other than a narrow ventilation hole, and no connection to the separate workings at the east shaft.

*Rocks.* The gold occurs in a generally flat-lying, oxidized, iron-rich siliceous vein in the margin of a small syenodiorite stock where it intruded Tin Mountain limestone of Mississippian age. The intrusive rock in the mine area is medium gray to medium dark gray and medium-grained to fine-grained. Some of the coarser-grained parts have conspicuously poikilitic biotite and some of the finer-grained rock has phenocrysts of hornblende as much as a centimeter long. A representative specimen from the hill above the mine is medium-grained augite syenodiorite. A thin section of it is composed of 44 percent calcic andesine, 20 percent orthoclase, 20 percent augite, 8 percent biotite, 5 percent magnetite and 3 percent accessory apatite and sphene. The rock is called syenodiorite, essentially equivalent to quartz-free granodiorite, because the orthoclase, which is about 31 percent of the total feldspar, is more than the 5 percent of the feldspar permitted in diorite, and less than the 35 percent required for monzonite. The variety containing poikilitic biotite, which produces a distinctive fracture of sharp angles between flat surfaces having a bronzy sheen, also is syenodiorite. A thin section of a specimen from a neighboring stock, about 4,000 feet south of the mine, consists of 50 percent andesine, 22 percent orthoclase, 14 percent augite, 9 percent biotite, 5 percent magnetite, and less than 0.4 percent apatite. Orthoclase is 31 percent of the total feldspar. Although variations may pass into monzonite or even diorite, all the intru-

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ive rock at the mine will be referred to as syenodiorite, articularly as the original nature of much of the country rock near the veins is obscured by alteration to a onspicuous amount of epidote and probably both hypogene and supergene clay.

The exposure of the small stock at the mine is at most 00 feet long and 300 feet wide and lies about a mile orth of the Sally Ann pluton of quartz-monzonite. The pluton is 5 miles long and is separated along the southern border by merely a narrow strip of marble from he quartz-monzonite batholith of Hunter Mountain. Syenodiorite, monzonite, and diorite at other places in he region occur along the borders of large quartz-monzonite masses that intruded limestone and dolomite. Thus the occurrence and kind of rock suggest that the ntrusive body at the Lost Burro mine is a border-facies atellite of the quartz-monzonite batholith.

The syenodiorite in the mine area metamorphosed the ormally dark and well-bedded Tin Mountain limestone o lighter gray or nearly white coarse-grained marble nd obscured the bedding. Calc-silicate minerals were ormed in a zone of varying width next to the intrusive ontact. The silicates, largely greenish-gray diopside nd grossularite, are too light colored and lacking in ron to make tactite in the strict sense. Locally at the ntrusive contact orthoclase, albite (including albite eplacement of orthoclase), epidote, and melanite were dded. Some of the black melanite forms an outer zone n pale yellowish brown garnet. This mixed rock underground, especially in argillized zones, hinders detailed apping of the intrusive contact. The proportion of alc-silicate minerals and coarse-grained calcite varies reatly within the zone. On the map (pl. 3) the zone hows the approximate limits of occurrence of the calc-silicates in marble.

*Structure.* The Tin Mountain limestone near the ine dips in general about 35° W. and strikes northwest, howing the change in strike from north in the mountain orth of the mine to east at a point within a mile south f the mine. The Devonian and Mississippian rocks of he entire mountain were overridden by the Racetrack hrust, which folded the underlying beds next to it. The hrust fault and the underlying folds were warped from northerly strike to an easterly strike about a mile outhwest of the mine. The overriding block and the hrust-fault zone have been eroded from the mountain o that the trace of the thrust fault, largely concealed y alluvium, runs along the western base of the mountain and up the canyon at the northern border of the Sally Ann pluton. Quartz-monzonite of the pluton solidified, where now exposed, after the thrusting and arping took place. The thrust-fault zone perhaps uided the injection of this part of the quartz-monzonite ass that finally warped the fault and the underlying olds.

Faults and shear zones in the mine area are local and f small displacement. The local shear zone that controlled the ore-bearing vein undulates in relatively gentle ips into the intrusive mass. In the opposite direction it ies out along the lower contact of a tonguelike apophysis. Later minor adjustment along the shear zone, after t was further weakened by hydrothermal argillation, ormed the gouge and slickensides that now are conspicuous selvages of the vein.

A steep fault that was mapped from the northeastern corner diagonally across the mine area is a reverse fault dipping 80° to 85° W. on which the vertical component of displacement of Tin Mountain limestone beds in the northeastern corner of the area is about 15 feet. About 500 feet southwest the vertical component of displacement of the vein underground is about 30 feet.

Another steep fault zone, dipping 60° to 80° S., is prominent in mine workings but is poorly exposed at the surface from the western margin of the mapped area to the west shaft. Underground the zone is exposed for about 120 feet on the lowest level (5,520 altitude) in the northern part of the mine and for 80 feet along a drift from the west shaft. The fault zone that continues from the west shaft northeastward and through a shallow incline probably is merely a branch, since it dips north instead of south and dies out 250 feet from the shaft. The main fault zone at the west shaft probably swings southeast under dumps and slope rubble down the main gulch, because from the shaft a drift about 60 to 80 feet beneath the gulch follows the south-dipping fault zone where it swings southeastward from the shaft and heads for the similarly trending south-dipping shear zone that is exposed along a northwest drift at the bottom of the east shaft. Neither ore nor barren vein has been found along this fault zone.

*Ore Deposits.* The gold ore was mined from a siliceous vein that ranges in thickness, in the walls of the workings, from a few inches to 4 feet but is commonly about 2 feet thick. If the stopes, however, represent the outline of ore, the deposit was as much as 8 feet thick off the 5,519 adit in the eastern part of the mine. Ore shoots in the vein, as indicated by stopes, lie within a length of 350 feet, a width of 50 feet, and a difference in altitude of 75 feet. Ore was mined on three levels, progressively higher toward the west, at places where the vein is nearly flat or dips gently east. Undulations account for some of the abrupt changes in strike and width of the vein at the map level.

The vein exposed along the cross cut from stopes on the 5,563 level to the vertical connection marked 5,585 is a local branch of the main vein. The branch splits by continuing the flat undulations of the main vein from the place where the main vein abruptly steepens upward to the 5,592 stope. The branch thickens to 2½ feet in the flatter part but after steepening again, it pinches out 8 feet above the floor.

A separate vein is followed by the steeply inclined east shaft. The vein, which lies about N. 60 E., 70 N., is commonly 6 inches thick and apparently barren. A drift along it for 65 feet, about 60 feet below the collar of the shaft, is narrow and low, as if only for exploration. The principal exploration from the east shaft was not along the vein but along an unmineralized shear zone normal to the vein. A drift from the bottom of the shaft follows the shear zone about 140 feet.

Minerals seen in the main vein include a little megascopic gold, chalcopyrite, and pyrite, and abundant iron oxides, in gangue of quartz, jasper, and some very coarse grayish calcite. The jasper is dull reddish or yellowish brown and cuts across shattered quartz. The sulfides were seen in quartz, but the gold was seen in jasper. How much of the mined gold was residual in the gossany iron oxides is not known. There are some supergene copper minerals in the vein outcrops and on the dumps. The east-shaft vein contains opal and jarosite along with hematite, limonite, and quartz.

No trace of scheelite was found by means of an ultraviolet lamp underground or in the more favorable calc-silicate zone on the surface. A Geiger counter failed to show radioactivity greater than the background.

Further exploration along the known ore-bearing structure in the Lost Burro area hardly seems warranted, as the ore-bearing vein does not penetrate the metamorphic rock and pinches out where it was followed into the syenodiorite. A small block of vein, at least 2 or 3 feet thick and flat-lying like stoped parts of the vein, remains between the adit and the main stope on the 5,519 level. This part, however, may not be within the assay limit of ore. The most favorable way to continue underground prospecting may be to sink farther in the east shaft, looking for other ore-bearing veins near the intrusive contact and parallel to the mined vein.

### Copper

#### Sally Ann Area

The copper deposits on the Sally Ann mining property are representative of the many small, scattered copper deposits in contact-metamorphic zones within the Ubehebe Peak quadrangle. Although the Sally Ann area has been unproductive in contrast to some of the other copper properties, which together produced at least 120,000 pounds of copper from 1908 to 1951, this example was selected for detailed mapping because it was the only copper property that had mining activity on it in recent years. From late in 1947 to mid-1948 Orval Huffman and J. R. Arnold, who with some associates held the Sally Ann claims, worked on the property. They drove an adit 117 feet in an attempt to cut the best exposed copper deposit about 65 feet below the outcrop. Older workings in the area consist of shallow pits and trenches. These copper deposits were known in 1905, according to claim notices of that date, and as early as 1902, according to a brief published description of the property then known as the Copper Knife (Aubury, 1902, p. 248).

The Sally Ann deposits are on a steep mountainside within a quarter of a mile east of the southern end of The Racetrack playa, and the deposits are between 150 and 500 feet above the playa or between 3,850 and 4,200 feet above sea level. They are in sec. 5, T. 15 S., R 41 E. (projected). The only access is across the playa from the road in Racetrack Valley. A cabin and two tent frames were constructed by Huffman and Arnold for the mine camp at the edge of The Racetrack playa. As there is no local source, water was hauled from Goldbelt Spring.

The geologic and topographic map of the Sally Ann area (fig. 25) was made by E. M. MacKevett with the assistance of the writer in 1948. The map, covering an area about 3,400 feet long and 1,800 feet wide, is based on plane-table triangulation from a baseline 1,200 feet long on the flat playa. The initial orientation was by compass, using a declination of 16° E. Much of the following information about the area is taken from an open-file manuscript report by MacKevett in 1949.

The showings of copper minerals are in contact-metamorphosed Paleozoic sedimentary rocks, which probably are in the Lost Burro formation of Devonian age. Most of the rocks now are nearly white marble recrystallized from limestone and dolomite, but they include some calc-silicate rock, and a little hornfels. The texture of the marble ranges from fine to coarse grained, and the nearly white color of the fresh marble weathers to tint of yellowish gray. The southernmost mass of recrystallized limestone, which is barren of copper minerals, retains a darker gray color, is thinner bedded, contains some chert, and on the eastern side has some vitreous quartzite; these characteristics suggest it is Tin Mountain limestone in contact with the quartzite in the uppermost part of the Lost Burro formation. The calc-silicate rock is largely tactite made up predominantly of garnet and some epidote, quartz, magnetite, antigorite, and chrysotile. A little of the contact-metamorphic rock, which has been designated hornfels (fig. 25), is much finer grained and is dark gray weathering dark brown. Some of the dolomite marble, especially next to dikes and apophyses, contains conspicuous quantities of light greenish phlogopite in flakes as much as a centimeter in diameter.

The intrusive rock in the adjacent plutonic mass is mostly quartz-monzonite but includes some irregularly distributed border facies, which in the mapped area occur largely in apophyses and dikes and consist of syenite and syenodiorite. The quartz-monzonite is composed essentially of orthoclase, plagioclase, and quartz, but contains varied proportions of much less augite, hornblende, and biotite. Sphene is a conspicuous accessory mineral. The syenite, which is medium light gray, contains little more than potash feldspar and locally conspicuous melanite. The texture, although highly varied, is mostly coarse grained. A thin section of a representative sample of the syenite shows orthoclase and some microcline as host of the albite in microperthite, which is largely a replacement type. Augite makes up about 4 percent of the volume; sphene and much less apatite, opaque grains, sericite, and calcite together make up about 1 percent. The syenodiorite, which is about the same gray, is finer grained. A thin section shows monzonitic texture and the following volume percentage of constituents: 57 percent plagioclase, 24 percent somewhat microperthitic orthoclase, 12 percent augite, 3 percent biotite, and 4 percent other accessory minerals—sphene, opaque minerals, and apatite.

The blocks of metamorphosed Paleozoic rocks are almost isolated by intrusive rock and appear to be roof pendants or irregular elongate protuberances from the southwestern wall of the intrusive mass. The regional geology shows that they once lay under a westward-dipping thrust fault that has a stratigraphic throw of about 8,500 feet. The thrust, where exposed 2,000 feet southwest of the area, placed The Racetrack dolomite of Cambrian age on the upper part of the Perdido formation of Mississippian age (fig. 9). The thrust fault here strikes north, parallel to the general strike of the beds in the Sally Ann area. The beds in the area dip steeply, from 75° E. through 90° to 80° W. The contacts with the intrusive rocks also appear to be steep, but there is nothing to indicate how deep the metamorphic rocks, hence the copper-favoring zones, go.

The spotty showings of copper minerals appear in two groups, which roughly determine the northern and southern limits of the mapped area. The northern group, which held the interest of Huffman and Arnold in 1948, consists of a zone about 350 feet long in marble at an intrusive contact, and of several spots isolated about 500 feet west in another block of marble at an intrusive contact. The southern group is about 800 feet long in tactite at an intrusive contact. Only shallow pits and trenches have been made in the mineralized rock; the Huffman adit in the northern group was driven along a minor fault through barren marble, in an apparently unsuccessful attempt to intersect the zone of copper showings that crops out about 65 feet higher. The copper-stained zones in general are from 2 to 10 feet wide, and are most extensive in the southern group, where tactite is the host rock.

The copper minerals that were seen are characteristic of the oxidized zone; the most conspicuous are malachite and greenish copper silicates, such as chrysocolla, and some azurite. A little scheelite, some of which is coarse-grained, was found by means of an ultraviolet lamp at several places along the southern part of the contact. The principal minerals associated with the copper minerals, especially in the southern group, include abundant magnetite, limonite, hematite, garnet, epidote, phlogopite antigorite, chrysotile, and a small amount of quartz.

The main structural control of the copper-mineralized zones is the easternmost contact of the metamorphic rocks with intrusive rock. The contact in general, as well as the bedding in the metamorphic rocks, is nearly vertical; consequently the copper zones, although not necessarily the individual showings, probably continue downward for a considerable distance. Steep zones of fault breccia and gouge, as much as a foot thick, are associated with some of the deposits, but it is not known whether they localized the original copper minerals as well as the supergene minerals. The few cross-cutting faults, which strike west and dip north where the dip is known, seem to be unrelated to the occurrence of copper minerals.

#### Copper Bell Mine

The copper deposits at the Copper Bell mine are geologically similar to those in the Sally Ann area, but they seem to have been of much higher grade. Much of the copper production reported from the Ubehebe mine, somewhat over 15,000 pounds (U. S. Bureau of Mines), may have come from the Copper Bell workings, for they are in the same group and have been held by the same owners. In 1952 the Copper Bell claims were held by Ubehebe Mines, Inc., (Grant Snyder, President) of Los Angeles. The mine, which is in sec. 1, T. 14 S., R. 40 E. (projected), is about 1,000 feet straight east of the Ubehebe mine and is 250 feet above the foot of a steep southwestward-facing hillside, at about 4,200 feet above sea level. A foot trail connects it with the Ubehebe mine road at the low divide west of Racetrack Valley, near the northern border of the Ubehebe Peak quadrangle.

The mine workings (fig. 26), which were mapped with Brunton and tape by E. M. MacKevett in January 1951, are on two overlapping but unconnected levels 21 feet vertically apart. The total length of the workings, including the deep open-cut approaches to the underground parts, is nearly 300 feet, about equally divided between the two levels. The upper workings, particularly the western part, contained most of the copper.

The copper deposits occurred largely in coarse-grained nearly white marble, which was recrystallized from the Pogonip limestone by a small stock. The upper part of the vertical beds is on the west side; for westward the stratigraphic sequence continues upward through the lower and upper units of the Eureka quartzite to where it is faulted against the Ely Springs dolomite in the Ubehebe mine area. Much less copper was deposited in tactite, which prevails in the lower workings. The tactite probably is in a siliceous and shaly part of the Pogonip limestone.

The main intrusive contact is as close as 25 feet northeast from the lower workings. The intrusive rock, which constitutes a small stock largely beyond the northern border of the quadrangle, consists of quartz-monzonite and border facies of syenite. The quartz-monzonite is much finer grained than most quartz-monzonite in the region. The syenite is characteristic of others in the quadrangle in that it is at contacts with marble or in dikes cutting through the marble, it is essentially orthoclase slightly albitized and epidotized, it contains erratically distributed melanite, and it has conspicuous and abrupt differences in texture. Some parts are aggregates of thinly tabular orthoclase grains as much as 10 cm long and between 0.5 and 1 cm thick. A mafic variety, minette, appears in dikes at the Copper Bell workings.

The copper minerals here include chalcopyrite, bornite, and melachite, associated with pyrite, hematite, and limonite. Some coloform chrysocolla on supergene brown jasper is covered with fine-grained calcite; some malachite on limonite is coated with clear drusy quartz. The gangue in some places, such as in the upper workings, is calcite and abundant quartz, and in other places, especially in the lower workings, it consists of typical contact-metamorphic minerals: garnet, epidote, greenish mica, and antigorite. Coarse-graind calcite, quartz, epidote, and a little fluorite are intergrown in massive garnet.

The occurrence of the ore coincides with the contact-metamorphic zone, and in detail may have been controlled somewhat by beds or fractures along the beds within the contact zone. Cross faults, which are minor, seem unrelated to the occurrence of the copper minerals. Considerable local fracturing shattered the hypogene deposits and facilitated supergene processes, which in turn have obscured the original relationships.

#### Ubehebe Peak Area

In the contact-metamorphic zone on the northeastern and northern sides of the Ubehebe stock, about 3 miles south of the Copper Bell mine, there are many old copper prospects, which early in the century were given sufficient attention for John Salsbury to establish a camp called Saline, northwest of The Racetrack (Aubury, 1908, p. 310, and map facing p. 300). Salsbury controlled the Sanger group of claims northwest of Ubehebe Peak, which probably included some of the following properties, accessible by faint trails from Racetrack Valley.

The highest copper prospect is the *Copper Queen No. 1* (see fig. 2), which lies at about 5,300 feet above sea level, half a mile north-northwest of Ubehebe Peak, and in sec. 26, T. 14 S., R. 40 E. (projected). According to the only claim notice seen there in 1949, it belonged to Henry Hagerman, Jack Foley, and Louis Hinds in 1945. There are several trenches and a shaft about 35 feet deep. The showings of supergene copper minerals are in typical contact-metamorphic rock of a septum about

50 feet wide, along the eastern side of a marble roof pendant. The southeastern contact of the septum strikes N. 45° E. and dips 65° SE. The intrusive rock here is coarsely porphyritic granite, which is a local facies in the Ubehebe Peak stock of quartz-monzonite.

At the western contact of another roof pendant or stoped block of marble, a claim called the *Copper Queen* (fig. 2) by Mark Hunter in 1950 is 1.3 miles N. 50° W. of Ubehebe Peak. It is in sec. 22, T. 14 S., R. 40 E. (projected). The workings, according to E. M. MacKevett, who supplied the information about this and the following locality, consist of two trenches (36 feet and 12 feet long) and a pit about 7 feet deep.

*The Copper Queen No. 2* (fig. 2), as it was called when relocated by Mark Hunter in 1950 but known as the *Gold Eagle* when held by William Graves in 1935, is about 800 feet east-southeast of the Copper Queen. The workings consist of a shaft about 60 feet deep, a small adit 20 feet long, and several trenches. The copper stain is in locally brecciated, highly iron-stained tactite at the southwestern contact of the same roof pendant or stoped block that contains the Copper Queen.

The *Blue Jay* mine, in sec. 22, T. 14 S., R. 40 E. (projected), and about 3,000 feet above sea level, is on the northern side near the bottom of a canyon $1\frac{3}{4}$ miles N. 52° W. of Ubehebe Peak (see fig. 2). The road from Saline Valley to the mine now is almost entirely washed out, making it difficult to reach the property. Although no claim notice was found here in 1950, the mine was identified by an old claim post marked Blue Jay opposite the adit, and by the reference to the Blue Jay in A. P. Mairs' claim notice of 1935 on an adjacent claim. In 1902 the Blue Jay belonged to Mairs (Aubury, 1902, p. 248). The only recorded production from the Blue Jay mine was by Mairs, who in 1915 shipped 20 tons of ore containing 4,000 pounds of copper and 1,199 ounces of silver (annual production records, U. S. Bureau of Mines).

The main workings consist of an adit nearly 100 feet long and a shallow winze about 60 feet from the portal. An old drilling rig remains in place west of the adit, and a line of shallow workings are along the western side of the tributary canyon from the north. Supergene copper minerals are in tactite from metamorphosed uppermost Lost Burro formation at the contact with quartz-monzonite of the Ubehebe stock. The spotty mineralization occurred in a north-trending zone about 500 feet long and produced copper deposits that are like the others described in contact-metamorphic rocks. The silver produced from the Blue Jay mine, however, is unexplained by the minerals seen there.

The *Bonanza* claim, which was known as the *Hessen Clipper* (Norman and Stewart, 1951, p. 141) before filing by George Lippincott, Jr., in 1951, is on the road between Racetrack Valley and Saline Valley, about $2\frac{1}{2}$ miles from the junction with the road to the Lippincott mine (see fig. 2). It is in sec. 10, T. 15 S., R. 40 E. (projected), and about 2,650 feet above sea level. The old Ubehebe Trail for pack trains from Owens Valley crossed the property and continued on up to the Bonnie Claire road in Racetrack Valley. Old workings consist of an adit 65 feet long and a shaft about 30 feet deep from the surface to the adit 50 feet from the portal; the shaft continues only about 5 feet below the adit.

The Bonanza copper deposit is much like the others in contact-metamorphic zones of the quadrangle. It is in a narrow septum of thoroughly metamorphosed Paleozoic rocks in a broad ill-defined fault zone; therefore the identity of the formation in which it occurs is questionable. Some Rest Spring shale, greatly sheared in the fault zone, poorly crops out a few hundred feet west of the mine. The fault zone extends along the entire southwestern contact of the septum as far as the Lippincott area, shearing quartz-monzonite along with the metamorphic rocks.

The deposit is irregular and now consists largely of supergene copper minerals in reddish-brown jasper. The principal mineralized part exposed underground is low grade according to a sample taken horizontally along a width of 4 feet on the southeastern wall of the shaft at the adit level. The sample, as assayed by Ledoux & Co. for the U. S. Geological Survey, contained: 1.87 percent copper, 0.02 ounces of gold, 0.30 ounces of silver, and 0.05 percent lead. A grab sample from the ore bin (in 1947) had 11.94 percent copper, 0.05 ounces of gold, 1.90 ounces of silver, and 0.03 percent lead.

Nearby contact-metamorphic rocks contain unusually large masses of coarse-grained diopside, which is locally stained with supergene copper minerals and is cut by some clear gray chalcedony. Moss agate is poorly developed at some spots. Other masses of metamorphic rock consist of anhedral wollastonite in blades 5 to 10 cm long, in which some partly oxidized chalcopyrite is disseminated. In a pit on the eastern side of the mine spur there are some veinlets and small patches of pink manganian zoisite (thulite), which in thin section is seen to have with it some scattered grains of sphene. This may be the source of the thulite reported in boulders from near the south end of Saline Valley, on the east side (Schaller and Glass, 1942, p. 519; Murdoch and Webb, 1948, p. 320). Some of the contact rock, which consists of intergrown garnet, a little calcite, and abundant idocrase, is noticeably more radioactive than the surrounding rock. An analysis of the aggregate gave 0.016 percent equivalent uranium and 0.008 percent uranium (Radiation—J. Rosholt, Chemistry—J. Meadows, written communication, 1951).

Half a mile straight east of the Bonanza property and on the northern side of the same metamorphic septum, other small workings were on the property of the *Inyo Copper Mines and Smelting Co.* The mining camp, in sec. 11, T. 15 S., R. 40 E. (projected), was on the old Ubehebe Trail. A brief statement accompanied by a photograph that identifies the locality, published early in this century (Aubury, 1908, p. 307), was encouraging about the prospects of the company, stating that it had done by far the most important exploration work in the Ubehebe district and that ore had been reported as assaying from 4 to 41 percent copper. Mining must have been disappointing, and no basis for the optimism remains.

Among the other copper prospects around the southern end of the Ubehebe stock, only the *Copper Giant No. 3* is mentioned here, since it has an adit somewhat over a hundred feet long, visible from the road south of the Racetrack. It is about half a mile west of the road at a place 1 mile north of the Lippincott mine junction, and is in sec. 12, T. 15 S., R. 40 E. (projected). In 1943 the claim was held by George Lippincott and

George Lippincott, Jr. The workings, however, clearly are much older than the claim notice, and they are located at the *Copper King* as cited by Norman and Stewart (1951, p. 139, no. 6 of pl. 1). The adit follows an iron- and copper-stained zone that is from about half a foot to a foot wide and lies S. 70° W., 50° NW., in a contact zone of intrusive rock against marble on the northwestern side.

More conspicuous outcrops of locally copper-stained tactite and masses of iron oxides mostly in tactite occur along the southern contact of the metamorphic rocks with quartz-monzonite within the Lippincott area (see pl. 2). A few chip samples taken at the better showings and analyzed by the U. S. Geological Survey contain little copper and no gold, silver, lead, or zinc.

#### Hidden Valley Area

The discovery of the *Ulida* copper deposit (see fig. 2), by William Hunter sometime before 1875, led to the opening of the Ubehebe mining district. In 1902 the Ulida group of claims was owned by Spear Bros. and W. L. Hunter (Aubury, 1902, p. 248); much later, in 1935, P. E. Day and Cliff Palmer relocated the Ulida mine under the name of *Morning Star mine*. Then in 1939, according to the only claim notices that remained on the property in 1949, it was filed as the *Walker mine* by W. G. Walker, and in 1947-1949 it was owned by Edna Horstmeier, who posted notices of assessment work. Although Walker mine is the most recent of the names that have been used for the mine, Ulida is well established in past and current usage.

The Ulida mine, in sec. 17, T. 15 S., R. 41 E. (projected), is 2 miles N. 70° W. of benchmark 4923 on the scraped road that is on the eastern side of Ulida Flat. Car tracks cross the flat to the foot of the ridge, to within half a mile from the mine. It is 2.1 miles straight east of the Lippincott road junction, south of The Racetrack, but this approach from the west is over a much longer, rougher, and steeper trail.

The Ulida copper deposit is typical of those in tactite at the contact of Paleozoic marble with intrusive rock. It lies at the tip of a southeastern prong from a block of Lost Burro formation, projecting into quartz-monzonite at the southern end of the Ulida stock. The iron- and copper-stained tactite in the outcrop trends about N. 65° W. and is practically vertical. The contact in detail is very irregular.

The *Shamrock claim* (see fig. 2), which is the name used by L. S. Barnes and R. C. Wright on their claim notice dated 1945, has a prospect working inclined about 35° for about 25 feet. It is 1½ miles S. 57° W. of benchmark 4923 at the road on Ulida Flat, and is in sec. 21, T. 15 S., R. 41 E. (projected). The copper minerals are in a well-brecciated contact-metamorphic zone in coarse-grained, nearly white marble, which is probably of the Lost Burro formation, and which is in contact with a mafic border facies of the quartz-monzonite batholith of Hunter Mountain. The minerals are characteristic of the other copper deposits in contact-metamorphic zones; copper silicate, malachite, azurite, some limonite and hematite, and much magnetite. Scapolite, partly stained green, formed anhedral crystals and some noteworthy euhedral crystals commonly 5 mm in diameter.

The *Big Rock claim*, held by W. C. Thompson and A. G. Borden in 1948, is about half a mile west of the road in Hidden Valley, 2½ miles south of the Lost Burro mine junction, and is in sec. 27, T. 14 S., R. 41 E. (projected). The following information is from field notes by R. F. Johnson, U. S. Geological Survey (1949). The workings, which are visible from the road, consist of an adit 75 feet long running N. 85° W., a 15-foot shaft a short distance up the hillside, and an open cut. The adit goes through marble to quartz-monzonite at the face, and the upper workings are in somewhat copper-stained tactite. The adit probably was driven in an unsuccessful attempt to cut the copper zone at the lower level.

A short adit, which was probably called the *East Star mine* by P. E. Day, is 0.4 mile west of the Hidden Valley road, a mile south of the Lost Burro mine junction, but the adit is screened from the road by a short north-trending spur. The locality, in sec. 22, T. 14 S., R. 41 E. (projected), is at the tip of a slender marble prong, which protrudes into the northern border of a quartz-monzonitic satellite of the Sally Ann pluton. The marble is a metamorphosed part of the Lost Burro formation. A vein in marble at the outcrop is iron stained and copper stained, but where exposed in the adit it is only an iron-stained zone in the intrusive rock.

#### Dodd Springs Area

The strip of metamorphic rocks trending southward from Racetrack Valley contains some small copper deposits in the area around the Dodd Springs (see fig. 2). The deposits are mostly in marble and calc-silicate rock, within short distances of contacts with quartz-monzonite on the west and gabbroic rocks on the east, but a few of the copper showings are in irregular veins of quartz in mixed metamorphic-igneous rock and in veinlets of tourmaline in lodelike clusters within the quartz-monzonite. The metamorphic rocks in the Dodd Springs area are probably Carboniferous and perhaps include the Tin Mountain limestone, the Perdido formation, and the Rest Spring shale.

The largest deposit in the group, and the only one described in any detail for this report, is on the *Shirley Ann claim*. Although it probably was worked originally for copper it now seems more promising for lead. The copper minerals are closely associated with the lead minerals. In addition to the usual green supergene copper minerals, some covellite occurs in separate grains, as a replacement of galena, and as an intergrowth with chalcocite. The short workings, which together make somewhat less than 200 feet, are about 1,000 feet southwest of Big Dodd Spring, part way up the southern slope of the gulch.

Copper prospects in the Dodd Springs area include short adits and pits that are probably on the old Trail claim and Dodd's Spring claim south of Big Dodd Spring, as mentioned in an early report (Aubury, 1902, p. 246). Surface workings on the northern side of the second ridge southwest of Big Dodd Spring perhaps are on the old Navajo Chief claim (Aubury, 1902, pp. 245-246). At the extreme southern tip of the metamorphic and mixed-rock zone, 1½ miles south of Big Dodd Spring, and on the trail between the spring and the Grapevine Canyon road, there are some showings of copper minerals in quartz on the Twin Sisters claim. On top of a ridge

1.2 miles N. 72° E. of Big Dodd Spring, copper and chalcocite associated with limonite after pyrite occur in tourmaline veinlets well within the boundary of the quartz-monzonite batholith at Hunter Mountain.

Also in the batholith but on the southern side of Hunter Mountain, some showings of supergene copper minerals occur in pegmatitic quartz. The occurrence is on the *Hourglass claim* (see fig. 2) of Beveridge Hunter and C. W. Fletcher in 1942 and is in sec. 21, T. 16 S., R. 41 E. (projected). The claim is 7,100 feet above sea level, about 1¼ miles N. 77° E. of the road junction at the divide between Mill Canyon and Grapevine Canyon or about 4,500 feet S. 30° W. of Jackass Spring. The bluish-green copper silicate is in minute veinlets through the quartz and makes finely colloform encrustations along more open fractures. A coarse-grained black mineral, associated here with the quartz and some potash feldspar, is allanite. It is clearly radioactive, presumably from thorium. The copper-stained patch is small in the pegmatite outcrop, which is about 100 feet long N. 70° W. and 50 feet wide.

#### Nelson Range

Few of the copper deposits in the quadrangle occur in veins that are sufficiently large and well defined to have encouraged mining. An example is at the *Copper Queen-Lucky Boy mine* (see fig. 2), which is in a gulch at the southwestern foot of the Nelson Range, about 6,300 feet above sea level, and in sec. 17 and 20(?), T. 16 S., R. 40 E. (projected). The only road from the mine is poor for 6 miles to a better road on Lee Flat, over which it is about 8½ miles to State Highway 190 at a place about 4½ miles northeast of the Darwin road junction. The mine was inaccessible below the short irregular workings on the adit level.

The copper deposit is in a quartz vein several feet thick in quartz-monzonite near the southwestern intrusive contact of a batholith against the Bird Spring(?) formation. South of the mine gulch, the quartz-monzonite and the vein are nonconformably capped with basalt. The latest faulting along the vein, which strikes N. 25° E. and dips 67° W., displaced the basalt a few feet relatively down on the western side. North of the vein at the mine, several other quartz veins, which are as much as 2 feet thick and occur in the quartz-monzonite, crop out longer distances in an area about 1,000 feet long. Although these other veins in some places are limonitic, they appear to be barren of copper minerals.

The conspicuous copper minerals in the quartz vein at the mine are malachite and light to moderate blue green copper silicate. Some chalcopyrite remains in massive quartz, and is replaced by a little bornite and possibly cuprite. Some pyrite also remains but most has oxidized to hematite and limonite. In a variety of shades of brown and forms, limonite is abundant. The gangue, in addition to quartz, contains some very coarse grained calcite, a considerable quantity of brown and red jasper, and some light-gray chalcedony. The content of gold is not known.

Other copper mines and prospects in the Nelson Range are clustered northwest of the highest peak in the range, marked Peak 7701. A poor road, continuing as far as the divide beyond the turn-off to the Cerrusite mine, provides access to short trails to the prospects.

A group of surface and shallow underground workings, which are the nearest to the road at a place 0.9 mile N. 50° W. of the peak, explore some copper-stained tacite. The workings are in sec. 7, T. 16 S., R. 40 E. (projected), and about 6,500 feet above sea level. The tacite is in masses of marble, probably of the Bird Spring(?) formation, intruded by quartz-monzonite. In addition to trenches and open cuts there is an adit about 75 feet long headed N. 40° E., and another adit about 90 feet long S. 87° E. The adits go through marble to tactite.

A showing of copper minerals in the *Pinion Extension* claim occurs along a fracture in mixed rock 0.85 mile N. 42° W. of 7701 peak. Another zone of copper stain along interlacing fractures in somewhat darker and finer-grained quartz-monzonite than usual is at the *Green Eye* prospect near the top of the east slope of the range, 0.75 mile N. 33° W. of the peak. The Pinion Extension and Green Eye claims are in sec. 7, T. 16 S., R. 40 E. (projected).

More accessible prospects are on the rolling-topped spur northeast of the end of the road, about 1.2 miles N. 25° W. of 7701 peak and in sec. 6, T. 16 S., R. 40 E. (projected). They are in contact-metamorphosed impure limestone and shale of the Bird Spring(?) formation and have some lead as well as copper minerals. The *May B* claim, as named by C. W. James in 1943, has a row of shallow workings; a central one is a shaft about 30 feet deep from which there is a short drift eastward. A vein, at about N. 75° E., 90°, consists of quartz, coarse calcite, some jasper, iron oxides, and probably some cerussite, and is somewhat stained with copper minerals. Some of the quartz stringers, which are mostly less than an inch thick or are pockets, contain galena. The westernmost working in the group is an adit about 60 feet long in a claim called the *Rambler No. II* by Elmer Otis in 1939. The adit follows a poorly developed vein along a shattered zone through somewhat metamorphosed shale. Some of the quartz on the dump is copper stained and has a trace of galena.

More extensive showings of supergene copper minerals remain at the *Anton and Pobst* mine, at the end of the trail that follows the eastern rim of the canyon, northward from the end of the road out of Lee Flat. (See fig. 2.) The mine, which is about 6,100 feet above sea level, is 1.6 miles N. 27° E. of Peak 7701 and in sec. 6, T. 16 S., R. 40 E. (projected). At the time of examination in 1949, the only claim notices on the property were dated 1943 or later and did not refer to the Anton and Pobst mine. A claim notice by C. W. James in 1943 and another by W. J. Johnson and Bert Quinn in 1947 called the claim the Valley View, and a claim notice by Jim Fagin in 1948 called it the Coffer Valley. The published descriptions of the location of the Anton and Pobst mine (for references, see Norman and Stewart, 1951, p. 139) are too brief or inaccurate to use. This mine was identified as the Anton and Pobst mine by E. M. MacKevett (oral communication, 1952) long after the field work, through conversations with miners at Lone Pine. The identification is significant in that the Anton and Pobst mine in one year produced about two-thirds of all the copper production recorded from mines in the quadrangle. During 1916, the single year of the mine's recorded production, 400 tons of ore containing 82,000 pounds of copper was mined from the Anton and obst mine (annual production records, U. S. Bureau f Mines). Underground workings, including a 40-foot dit, are about 100 feet long in irregularly copper-ained marble and epidotized rock. The marble is meta-orphosed Bird Spring(?) formation, near the contact ith quartz-monzonite. The outcrop of the contact on e east is here concealed by a remnant of a basalt flow.

### Tungsten

#### uprotungstite (Alvord?) Claim

The best scheelite occurrence that is known in the uadrangle is on the Cuprotungstite claim (see fig. 2), long a trail from Racetrack Valley to Big Dodd Spring. t is about 2½ miles from the northern end of the trail t the Lippincott mining camp about 4,480 feet above ea level, and in sec. 30, T. 15 S., R 41 E. (projected). he owner of the Cuprotungstite claim in 1949 was oscoe Wright, who has held it since 1945. Older claim otices call it the Honolulu claim of Wallace Todd and ssociates in July of 1941, and the Carol claim of Ira lein and F. R. Kelley in February of 1941. Perhaps t is in the old Alvord group, which was located in 1916 y William Elliot, Ray Spear, and Ross Spear and was escribed as containing scheelite associated with copper nd iron minerals (Waring and Huguenin, 1919, p. 131). he 20-foot open cut, which extends a few feet under-round, appears to have been made long before 1940.

The scheelite is coarse-grained, as much as 2 inches in iameter but more commonly 1 inch or less. Almost all he scheelite is concentrated in a small area about a foot ong and half a foot wide in the face of the shallow vorkings. Much of the scheelite is a characteristic yellow reen of cuprotungstite, and it is associated with mala-hite and chrysocolla. The gangue, which contains much imonite after pyrite, consists of garnet, quartz, and alcite. Other minerals include hematite, magnetite, and halcopyrite. A polished section shows that there is a ittle bornite with the chalcopyrite, and that some chal-ocite, veined with cuprite, rims and transects chal-opyrite.

The deposit is isolated in marble of the Pogonip lime-stone, and it is about 500 feet from the exposed contact of the quartz-monzonite batholith at Hunter Mountain. It is not in a general zone of tactite and does not encour-age, under present working conditions and isolation, further exploration of the tungsten occurrence.

#### Monarch Mine

The only ferberite occurrence known in the quadrangle s at the Monarch mine in sec. 35, T. 15 S., R. 41 E. (projected) 0.9 mile N. 69° W. of Spanish Spring on Hunter Mountain. The mine is about 800 feet from the end of the jeep trail that starts at the road across Hunter Mountain about 23.5 miles from California High-way 190. A small production of tungsten in huebnerite was reported in 1915 from the Monarch mine, which at that time consisted of a 50-foot shaft and two 50-foot drifts at the bottom (Waring and Huguenin, 1919, p. 131). The workings were inaccessible when the property was examined in 1953. Claim notices dated 1941 by Bev Hunter, Elden Mason, and Johnnie Hunter and 1950 by W. O. Fraser and A. D. Fraser call the claim the El Capitan.

The shaft of the Monarch mine is on a lode about 6 inches thick oriented N. 40° W., 80 NE. Veins in the lode, where visible near the collar of the shaft, are commonly less than an inch thick, but fragments on the dump contain veins as much as 3 inches thick. The lode follows a limonite-stained, caliche-impregnated fractured zone in partly argillized quartz-monzonite. The vein minerals seen on the dump include quartz, calcite, ferberite, limonite, and traces of supergene copper minerals. The ferberite is brownish black and moderately coarse grained, has submetallic luster and perfect cleavage, and occurs conspicuously in the quartz. The mineral is identified as ferberite rather than huebnerite because a quantitative spectrographic analysis of a typical specimen shows much iron and little manganese with the tungsten.

## OUTLOOK

The mines in the Ubehebe Peak quadrangle will probably continue to produce small quantities of metals from the lead-zinc-silver deposits and perhaps nothing from the gold, copper, and known tungsten deposits. New lead-zinc-silver ore bodies probably could be found by further exploration in the few mines that have produced these metals. The small outcrops of the deposits have been no indication of the size of the particular ore body, but rather have been a guide to areas for mining exploration. Beneath some outcrops of the ore deposits, the guiding stringers have been slight and the controlling structure obscure. Exploration thus far has been shallow, at most a few hundred feet below the surface. The practical question, whether undiscovered ore shoots can be found without excessive exploration, remains unanswered.

Further production of gold and copper, other than as a by-product, under present conditions seems unlikely. The richer parts of the deposits seem to be mined out, and the geologic basis for more exploration is discouraging.

Prospecting for new discoveries of ore deposits of the metals that have a long history of prospecting, such as gold, copper, silver, and lead, is not encouraging because the region was thoroughly covered by the early prospectors. The outlook is better for finding unlocated deposits of talc, chrysotile asbestos, and possibly radioactive minerals, but is better especially for finding tungsten. Prospecting for scheelite probably has been less thorough than for other kinds of metallic deposits, because the search for scheelite is much more recent, and scheelite is more difficult to detect except by means of ultraviolet light. An ultraviolet lamp obviously is difficult to use in rough and isolated country. Tactite, which is favorable for the occurrence of scheelite, as in the nearby Darwin district and the highly productive Bishop district, occurs widely in the Ubehebe Peak quadrangle, and moderately widespread traces of scheelite indicate that at least some tungsten here also was in the mineralizers.

## ANNOTATED LIST OF MINERALS

Minerals that have been identified in specimens of ores and rocks from the area are arranged alphabetically, following the plan in the latest edition of *Minerals of California* (Murdoch and Webb, 1948). Mineral localities in the area are described for some of the less common minerals and for some of economic interest; many of the localities are cited merely as representative occurrences. From a mineral collector's viewpoint few of the minerals make showy specimens, because a great many are in granular aggregates of anhedral or subhedral crystals of ordinary size.

Chemical constituents and determinative tests are included where they may be of some particular interest or where there is some close similarity among the minerals. The compositions and characteristics of all are readily available in standard references, including *Minerals of California.* The physical characteristics described herein, such as some optical properties and some specific gravities, are mostly approximations sufficiently close for identification of the minerals. A few exceptions in precision are the contributions by specialists of the U. S. Geological Survey. The names and symbols for colors are according to the Rock-color Chart (Goddard et al., 1948), which is based on the Munsell system. Color symbols are used despite the implication of greater exactness than intended.

#### Allanite

Coarse-grained allanite occurs in a pegmatite that is about 4,500 feet S. 30° W. of Jackass Spring, at the southern edge of the highland on Hunter Mountain. The allanite occurs with copper-stained quartz in a shallow prospect pit on the Hourglass claim (see fig. 2) of Beveridge Hunter and C. W. Fletcher in 1942, and it is at the eastern end of the pegmatite outcrop, which is about 100 feet long, N. 70° W., and about 50 feet wide. The pegmatite is in the quartz-monzonite batholith at Hunter Mountain. Quartz greatly predominates in the pegmatite but with the allanite is some orthoclase, which is moderate orange pink (5 YR 8/4) to moderate reddish orange (10 R·6/6). The orthoclase appears to be intergrown with the allanite but at least some of it is replaced and microveined by allanite.

The allanite in grains as much as 4 inches long is black, or greenish black, perhaps from an altered film along fractures, for some of the alteration products are varied shades of olive and greenish yellow. In fragments and thin sections, the allanite is pleochoric in browns. The luster, where not dulled from alteration, is submetallic to resinous. The allanite is noticeably heavier than similar dark silicates; the specific gravity of a sample, as determined by means of a pycnometer, is about 3.9. Hand specimens are distinctly radioactive on a Geiger counter and thereby attracted further attention to the mineral after it was collected.

Identification of the allanite was tentatively confirmed by J. W. Adams of the U. S. Geological Survey (written communication, 1952). The following data reported by written communications in 1952, from members of the U. S. Geological Survey, verify it. According to J. Berman, "X-ray diffraction discloses that it is partially metamict. After being ignited it gives an excellent X-ray powder pattern identical to our standard for allanite." A semiquantitative spectographic analysis by Charles Annell shows that the allanite sample contains more than 10 percent cerium, aluminum, and silicon; from 1 to 10 percent iron, lanthanum, neodymium, thorium, and calcium; from 0.1 to 1.0 percent magnesium, titanium, praseodymium, manganese, gadolinium, samarium and yttrium; from 0.01 to 0.1 percent lead, copper, cobalt, strontium, and vanadium; and from 0.001 to 0.01 percent gallium, scandium, barium, and ytterbium. The radiation, in two determinations by B. A. McCall, is equivalent to 0.22 and 0.20 percent uranium. Chemical analyses by M. Delevaux show that the same samples contain only 0.004 and 0.003 percent uranium. The radioactivity presumably is produced mainly by the 1 to 10 percent thorium.

#### Amphibole Group

Small quantities of *actinolite* occur with coarse-grained scapolite and a little diopside and sphene in quartz-monzonite in zones of contact with marble, in at least three widely spaced localities: the Panamint Range southeast of the Lippincott mine, the southern slope of Ubehebe Peak, and in the Nelson Range north of the Cerrusite mine. This actinolite in hand specimens is dusky green (5 G 3/2), and forms elongate grains that have characteristic amphibole cleavage. The green color distinguishes it from tremolite, and the greatest refractive index near 1.644 distinguishes it also from hornblende.

*Hornblende* is the principal dark mineral in a wide variety of the intrusive rocks. It is the only dark mineral in some of these rocks, whereas in others it occurs along with biotite or augite or both. In quartz-monzonite, which is by far the most abundant intrusive rock in the quadrangle, hornblende is the principal mafic constituent, and in many parts it is the only one, ranging in quantity from accessory to as much as 14 percent of the volume of the specimens that have been micrometrically analyzed. Hornblende is conspicuous also in syenodiorite, monzonite, and some pegmatite, and it is accessory in diorite, granodiorite, leucocratic granite, and aplite. The coarsest grained hornblende seen, individually as much as 2.5 inches long, is associated with orthoclase and quartz in thin pegmatites a quarter of a mile east of Little Dodd Spring. The greatest proportion of hornblende found in any of the intrusive rocks is 74 percent, in a lamprophyre dike cutting quartz-monzonite at a seep 1.15 miles N. 40° E. of Big Dodd Spring. The lamprophyre contains 14 percent plagioclase (labradorite) and 11 percent augite. Hornblende occurs also in some of the tactite, with brown andradite and some quartz and calcite.

Fine-grained *tremolite* occurs in single needles and small bundles scattered through incipiently metamorphosed dolomite at many places in the quadrangle. A readily accessible locality is in the hills at the southern edge of The Racetrack playa, where tremolite grains are commonly 3 mm long in medium dark gray Racetrack dolomite. The colorless grains weather grayish orange (10 YR 7/4). Nearer intrusive contacts some chert nodules in dolomite were metamorphosed to tremolite aggregates or to rims of tremolite around cores of coarse-grained diopside. At the contact of quartz-monzonite with marble of the Lost Burro formation south of the Lippincott mine, tremolite forms light bluish gray radial clusters of slender grains or fibers that are commonly 3 to 5 mm long. Although it looks like radial pyrophyllite, it is harder and has the following higher indices of refraction: nX between 1.596 and 1.608, nY between 1.608 and 1.614, and nZ between 1.620 and 1.627. The maximum extinction between Z and the length of the fibers is about 17°. The tremolite is associated with some calcite and limonitized pyrite.

Pale-blue to duskier-blue fibrous amphibole may be a soda tremolite. It occurs in a thin veinlet through marble the Pogonip limestone near the contact with syenite, ›rtheast of the Ubehebe mine.

### Andalusite (Chiastolite)

A chiastolite form of andalusite occurs widely in con-ct-metamorphosed Rest Spring shale. It forms roughly ctangular grains commonly 3 to 5 mm long and a milli-eter in diameter. It is a greenish gray sufficiently anslucent to appear dark gray like the enclosing horn-ls, or the grains are white from alteration to sericite id kaolinite. The white grains show most clearly the mmetric concentration of dark carbonaceous particles ong diagonal planes and squarish cores, making the stinctive chiastolite patterns. The optical properties e normal for andalusite. The matrix, which is not foli-ed, consists of fine-grained quartz, biotite, and much rbonaceous material. The most accessible occurrence of iastolite is along the San Lucas Canyon road near the nction with the road to Cerro Gordo mine.

### Anglesite

Little anglesite was identified in the oxidized lead posits of the quadrangle; the abundant direct oxida-m product of galena is cerussite. Some anglesite makes in rims around grains of galena, penetrating along ie galena cleavage, and is intimately associated with russite, as in a specimen from the upper north stope the Ubehebe mine. It is associated also with arsenian inadinite, wulfenite, quartz, dolomite, and ochre. Some iglesite makes thin colloform bands between galena id cerussite, as seen in a polished section of ore from e Shirley Ann mine, where it is associated with covel-te and chalcocite.

### Antigorite

See serpentine group.

### Apatite

Apatite is an accessory mineral in all varieties of plu-mic rock in the quadrangle, and in some of the contact-etamorphic rocks. Apatite in the usual hexagonal risms is inconspicuous except in some thin sections. It well developed in the more calcic intrusive rocks, ich as in the hornblende-augite-labradorite lampro-hyre northeast of Big Dodd Spring, and in some of ie diorite east of the Dodd Springs. Apatite in a iartz-monzonite southwest of Ubehebe Peak has gray-h zones darker in the centers of grains, and some of has zonal arrangement of minute inclusions. Most of ie apatite, however, is clear. In contact-metamorphic ›cks some examples of the mineral assemblages con-iining apatite are: a little plagioclase, epidote, zoisite, ›hene, and magnetite in quartzite east of The Race-ack; epidote, orthoclase, diopside, and sphene, in the entral part of the Nelson Range; and plagioclase, diop-de, epidote, and sphene, in San Lucas Canyon.

### Aragonite

White or colorless crystals of aragonite line fissures i the Taylor shaft, the Addison incline, and the main orkings of the Lippincott mine. The crystals are cicular or lath-shaped, and are as much as half an inch ›ng. The flatter crystals resemble some of the euhedral rystals of hemimorphite, but the aragonite effervesces i cold dilute hydrochloric acid. Unlike calcite, the aragonite lacks rhombohedral cleavage, is biaxial, and has no index of refraction lower than 1.53. No index of refraction is as high as the lowest of cerussite. The arago-nite occurs near these minerals.

### Axinite

Coarse-grained axinite, found by R. F. Johnson (U. S. Geological Survey notes, 1949) occurs in calcite mar-ble very near the contact with quartz-monzonite. The locality (No. 2, fig. 2) is near the base of the mountains west of Hidden Valley, about 1.7 miles N. 78° E. of the Sally Ann adit. The axinite is purplish gray, in vuggy aggregates of platy subhedral crystals as much as an inch in the longest dimension, with euhedral parts ex-tending into small cavities. In fragments under a micro-scope the axinite shows a pleochroism from yellowish or colorless to purple; a very large negative optic angle; and strong dispersion, r less than v. Intergrown with the axinite there is a little quartz and some subhedral epi-dote, which is euhedral where it projects into cavities. A very little stilbite forms clusters of minute crystals on axinite.

Small white euhedral crystals of axinite are reported to occur with smithsonite in the Ubehebe mine (Eakle, 1923, p. 188; Murdoch and Webb, 1948, p. 61), and the occurrence is said to be confirmed by a later find at a locality that is described as the southern end of Butte Valley, Ubehebe mining district (Murdoch, 1949, p. 522). As Butte Valley is another name for Hidden Val-ley (Palmer, 1948, p. 36), the locality of the later find is perhaps the same as Johnson's but is probably not at the Ubehebe mine, which is 6 miles toward the northwest and in other mountains.

### Azurite

Although azurite occurs among the supergene min-erals at some of the widely spaced copper deposits, in the exposures at the time of the field work the quantity was greatly subordinate to that of malachite or of copper silicates.

### Barite

Coarse-grained barite occurs in a vein about 1,400 feet S. 85° W. of the highest point on the ridge back of the Lippincott mine. (See pl. 2). The barite occurs with quartz and limonitized pyrite in the vein, which is from 6 to 12 inches thick, and which crops out for about 25 feet in quartz-monzonite. The white barite is anhedral or subhedral and exhibits well the typical cleavage. A somewhat lamellar structure is outlined by limonitic stain. The specific gravity of a sample that has films of limonite on some fragments is, by pycnometer, about 4.3, which clearly distinguishes barite from other mem-bers of the group.

### Biotite

Biotite is a varietal or accessory mineral in many of the intrusive rocks in the quadrangle, and it is a constit-uent of some contact-metamorphic rocks. In quartz-mon-zonite, which is the principal intrusive rock in the quad-rangle, biotite commonly constitutes less than 5 percent of the volume and is subordinate to the hornblende. In the few thin sections of monzonite that have been ex-amined, biotite where present is subordinate to either hornblende or augite. In some of the syenodiorite, bio-tite is a varietal mineral subordinate to augite, and where present in the diorite or gabbro, it is subordinate to hornblende or augite. Where present in the granodiorite, biotite with few exceptions equals or predominates over either the hornblende or the augite. Biotite is accessory in some aplite and pegmatite, and it is an abundant essential mineral in the small quantity of minette that occurs in the quadrangle. Some of the biotite, as in a 3-foot dike of quartz-monzonite in hornfels east of The Racetrack, contains symmetrically oriented capillary crystals, and dark haloes around minute, clear grains.

Biotite is most conspicuous in the minette, which makes dikes in dolomite at the Ubehebe mine. The brown biotite, in flakes commonly 2 to 5 mm in diameter, constitutes 45 percent of the volume of the minette, which contains 32 percent potash feldspar (both orthoclase and microcline), 14 percent aegirine-augite, 4 percent calcite, and 5 percent accessory sphene, apatite, magnetite, and epidote. The biotite has a pleochroism of moderate yellow (5 Y 7/6) for X and dusky yellow (5 Y 6/4) for Y and Z, a very small negative optic angle, and an index of refraction about 1.65 on cleavage flakes. The thin biotite plates, which are roughly alined in the rock, are enclosed in feldspar, but some plates continue across the boundaries of feldspar grains.

Andalusite hornfels, such as the metamorphosed Rest Spring shale a mile south of the Cerro Gordo road junction in San Lucas Canyon (No. 1, fig. 2), commonly contains from 15 to 20 percent biotite associated with andalusite, quartz, and carbonaceous material. At the contact between monzonite and marble west of Hidden Valley, coarsely banded rock composed of augite and highly calcic plagioclase contains abundant biotite in the augite bands.

#### Bornite

A little bornite is associated with chalcopyrite and chalcocite, as seen in a polished section of copper ore minerals from the Cuprotungstite claim north of Big Dodd Spring. (See fig. 2.)

#### Calcite

In addition to the great quantity of fine-grained calcite in the Paleozoic limestones and the coarse-grained recrystallized calcite in marble at contacts of limestone with intrusive rocks, calcite is commonly a vein mineral and part of the gangue in the ore deposits. In tactite the calcite, against which garnet and epidote formed crystal faces, is the first mineral to weather away, leaving crystal-lined cavities. In contrast, moderately large calcite crystals line cavities in dolomite marble along part of the main adit of the Lippincott mine. Some calcite, associated with antigorite and chrysotile in ophicalcite, was produced by dedolomitization. Calcite that is probably accounted for by late contamination of an igneous rock by the wall rock occurs in minette at the Ubehebe mine. About 4 percent of a minette thin section consists of calcite, much of which is coarse grained against sharply defined faces of the silicate minerals.

Vein calcite along with jasper and quartz is the principal gangue mineral in some parts of the Lost Burro mine, where anhedral crystals are as much as a foot in diameter. Some of it here, as also in the Lippincott mine, is grayish or brownish, but effervescence in cold dilute hydrochloric acid and the refractive indices show that it is not siderite, ankerite, or dolomite. A little of the vein calcite fluoresces moderate orange pink or moderate reddish orange, as in a thin vein in the lower part of the Addison workings and in the open cut near the mai shaft of the Lippincott mine, where the calcite contair galena.

#### Cerussite

Cerussite, derived from the oxidation of galena, is common lead ore mineral in the deposits of the qua rangle, and in many outcrops and exposures left in th mines cerussite is the greatly predominant or the onl lead mineral. The best localities for finding cerussite a in the main workings of the Ubehebe, Lippincott, an Shirley Ann mines. The cerussite occurs in friable mi tures with limonitic material; in solid translucent masse fine-grained submetallic to somewhat waxy gray mass that are nearly opaque from minute inclusions; an in euhedral or subhedral clear crystals lining ca ities. Some of the cerussite directly replaces galena, r taining specks of galena, which are galena white i polished sections and opaque in fragments, and whic diminish in number and size outward from the unaltere core of galena. As traces of anglesite also replace son of the galena along the cleavage and between cerussi and galena, the identity of this cerussite was verified b optical properties and negative tests for sulfate.

Some other supergene minerals, namely, euhedr hemimorphite, wulfenite, and quartz, have crystallize on the cerussite. Other supergene minerals associate with cerussite include arsenian vanadinite, hematit chalcedony, calcite, aragonite, dolomite, clay mineral and at a few places some copper minerals such as chalc cite and covellite.

#### Chalcedony, Including Jasper

Chalcedony constitutes the relatively minor quanti of chert in the Paleozoic sedimentary rocks. Color brown and red by iron oxides, chalcedony is common i the metalliferous deposits and is most conspicuous in t many scattered copper deposits in contact-metamorph zones. Jasper is used in the text for this somewhat i pure chalcedony colored reddish or brownish, and cha cedony refers to the translucent white or light-gr material. A large part of the jasper seems to be clear related to supergene alteration.

#### Chalcocite

The chalcocite is an alteration of chalcopyrite, a probably to some extent occurs at the many localiti where there is some readily visible chalcopyrite, but on small quantities of chalcocite have been noticed. Chalc cite in a polished section from the Cuprotungstite clai surrounds chalcopyrite and is veined with cuprite. one from the Shirley Ann mine, chalcocite along wi covellite replaces galena and is bordered with cerussit

#### Chalcopyrite

Chalcopyrite is the general source of the widely sca tered supergene copper deposits. Green and bluish supe gene copper minerals are conspicuous guides to the sm quantities of chalcopyrite that remain unoxidized. T chalcopyrite occurs most widely in tactite and close associated marble, as at the Copper Bell and Shirley A mines, but it occurs also in well-defined quartz-calci veins, best exemplified at the Copper Queen-Lucky B mine. (See fig. 2). Within tactite the principal chalcop rite occurs in quartz and calcite; some of the chalcop rite, however, is disseminated through other mineral 'or example, the individual grains as well as clots and tringers are scattered through very coarse grained vollastonite near the Bonanza mine. The chalcopyrite lters to combinations of chalcocite, covellite, bornite, ınd cuprite, supplying copper also for chrysocolla, malahite, and azurite, and iron for limonite. Pyrite, mostly ıow oxidized to limonite and earthy hematite, persistntly accompanies the chalcopyrite, whether alone or vith scheelite, galena, or a little tetrahedrite.

#### Chlorite Group

Chlorite occurs as an alteration of biotite in some ntrusive rocks and some contact-metamorphic rocks, uch as a highly carbonaceous hornfelsic rock of quartz, ıuscovite, biotite, and tourmaline. In a quartz-bearing ıonzonite that is well albitized and somewhat sericitized bout 1½ miles south of Big Dodd Spring, the chlorite s ordinary prochlorite, for the interference figure is ptically positive, practically uniaxial, the birefringence s weak, showing an anomolous blue, and the index of efraction on cleavage flakes is about 1.60. The conpicuous greenish mica in silicated zones of contactıetamorphosed dolomite is not chlorite but phlogopite.

#### Chrysotile

See serpentine group.

#### Chrysocolla

Chrysocolla, perhaps accompanied by other copper ilicates, is the most abundant copper mineral left exosed at the many widely distributed copper-bearing leposits. Its colors are varied blue greens grading into ight blue. It is opal-like in form and makes some colloorm encrustations in cavities. The chrysocolla commonly oats brown jasper, and in some places it is covered with rusy quartz. Malachite is the most commonly associated opper mineral, but chalcopyrite and its supergene prodıcts generally occur nearby.

#### Clay Group

Clay minerals presumably make up a large part of the haly beds in the Paleozoic sequence, where the rocks re not metamorphosed. They occur also in weathered eldspathic rocks, playa deposits, earlier lake sediments, nd in gangue of some of the mineral deposits, but little atisfactory determinative work has been done on them. 'he clay fraction of a sample of playa sediment from the outhern end of The Racetrack playa is probably a mixure of illite and montmorillonite, as deduced from poor urves of thermal analyses, staining tests, and indices of efraction. The clay mixture was transported into the laya because the intermixed sand and silt-size grains f other minerals, are clear and unweathered.

Most of the clay in the metallic deposits is mixed with imonite in earthy masses, but some clay remains in urer aggregates of small size. Exceptionally, such as long some gouge zones next to the main vein in the Lost Burro mine, it is in larger unctious masses.

#### Covellite

Small quantities of covellite, along with chalcocite, eplace chalcopyrite and galena. Covellite rims some halcopyrite in quartz, which also contains pyrite and ıuch limonite at a prospect on the southwestern side of he main ridge back of the Lippincott mine. Covellite and chalcocite in a polished section from the Shirley Ann mine replace galena and are bordered by cerussite. These probably are representative of minor occurrences of covellite at the many prospects that contain some chalcopyrite altering to supergene copper minerals.

#### Cuprite

Cuprite, visible in a polished section from the Cuprotungstite claim, makes veinlets through chalcocite that has replaced chalcopyrite.

#### Cuprotungstite

On the Cuprotungstite claim, which is 1.3 miles N. 16° E. of Big Dodd Spring, cuprotungstite colors much of the coarse-grained scheelite a characteristic light olive (10 Y 5/4) grading into moderate greenish yellow (10 Y 7/4) and moderate yellow green (5 GY 7/4). The cuprotungstite appears to replace scheelite gradationally from fractures. The greenest parts, if fluorescent at all, are much less fluorescent than the nearly colorless scheelite. Some of the cuprotungstite-scheelite combination is coated with chrysocolla, which occurs also in the calcite-quartz-garnet-limonite gangue.

#### Dolomite

Fine- to coarse-grained dolomite is an abundant constituent of the Paleozoic rocks that are older than Mississippian and of marble derived from them in contact-metamorphic zones. Dolomite in the sedimentary rocks seems generally to be an original or diagenetic constituent rather than a late, magmatic replacement of limestone, because the dolomite parts of the sequence persist regionally, irrespective of relationships with the exposed intrusive contacts. At some of the mineral deposits the country rock is dolomite, as at the Ubehebe mine, or dolomite marble, such as some of the country rock at the Lippincott mine. A little dolomite occurs both early and late in the gangue at these mines, but calcite is the common carbonate in the gangue. Drusy, clear rhombohedrons of supergene dolomite crystallized at the same time as some euhedral hemimorphite.

#### Epidote

The best-developed epidote is found next to calcite in tactite, where it is in some moderately large euhedral crystals. Also in tactite, epidote replaces parts of some large subhedral crystals of brown-zoned garnet, favoring particular zones in the garnet. Light-colored, fine-grained calc-silicate rock, such as the diopside-plagioclase rock in San Lucas Canyon, also contains some epidote. Perhaps the widest occurrence of epidote is in veinlets and irregular replacement of albitized plutonic rock and mixed rock near contacts. In mixed rock at the crest of the Nelson Range, north of the Cerrusite mine, moderate greenish yellow (10 Y 7/4) epidote, which is lighter colored than most but has normal optical characteristics, is associated with albitized orthoclase, diopside, heulandite, sphene, and apatite, and nearby in similar rock with melanite.

#### Feldspar Group

Feldspars constitute the great bulk of igneous rocks in the quadrangle, a small part of the metamorphic rocks, and a considerable part of the Cenozoic sedimentary material derived from these rocks. Feldspar is practically absent in the Paleozoic sedimentary rocks, and in the metalliferous mineral deposits.

Orthoclase is much more abundant than microcline. Orthoclase is the principal potash feldspar in the quartz-monzonite, which is the greatly predominant plutonic rock. Microcline, however, is a major constituent in some of it, such as the leucocratic quartz-monzonite in the mountain about 1½ miles south of the Lippincott mine, and in some syenite and pegmatite. Both microcline and orthoclase are prominent in minette at the Ubehebe mine. The largest crystals of orthoclase are phenocrysts as much as 5 inches long and 4 inches wide but not as much as 1 inch thick (prevalent sizes are about 2 inches long and a quarter of an inch thick), which compose from one-fourth to three-fourths of the porphyritic granite exposed in the Grandstand and on the northeastern side of Ubehebe Peak. (See fig. 2.) The phenocrysts are irregularly perthitic Carlsbad twins. Many are somewhat broken within the groundmass, and they do not weather as whole euhedral crystals. In contrast, some small euhedral and subhedral orthoclase crystals, less than half an inch long, occur in coarse-grained hornblende with some quartz in thin pegmatites east of Big Dodd Spring. Small masses of syenite, as in the Sally Ann area and near the Ubehebe mine area, consist almost entirely of coarse-grained perthitic orthoclase. Perthitic association of sodic plagioclase in orthoclase and microcline is particularly common in syenite and pegmatite but occurs in some quartz-monzonite and some granite near contacts. Antiperthitic orthoclase in calcic plagioclase is well developed in a facies of the gabbro about 2,000 feet east of Big Dodd Spring.

The common plagioclase in the plutonic rocks is either oligoclase or andesine. Albite occurs in microperthite, and it replaces much of the feldspar at many places along intrusive contacts, especially in mixed rock at contacts. Labradorite is the feldspar in the olivine-basalt and in some gabbroic facies of plutonic rocks east of the Big Dodd Spring; the most calcic part contains bytownite approaching anorthite. The feldspathic, lighter part of banded gabbroic rock associated with pyroxenite between monzonite and marble in a small area on the western side of Hidden Valley is anorthite.

#### Ferberite

Brownish-black (5 YR 2/1) ferberite in vein quartz was collected on the dump at the inaccessible workings of the Monarch mine. According to a quantitative spectrographic analysis (H. W. Johnson, analyst) that shows much iron and little manganese, the tungsten mineral in a typical specimen from the dump is ferberite. The tungsten ore mineral at the Monarch mine according to previous reports is huebnerite (Waring and Huguenin, 1919, p. 131) and wolframite (Murdoch and Webb, 1948, p. 313). The ferberite occurs in irregular masses of moderately coarse anhedral and subhedral crystals. It has perfect cleavage, submetallic luster, and brownish-black streak. Although the ferberite occurs in quartz, calcite is a common constituent of the veins; limonite and supergene copper minerals stain some parts of the veins.

#### Fluorite

A little fluorite occurs with epidote in calcite of the tactite at the Copper Bell mine. The fluorite, which is in small clusters of anhedral and subhedral crystals, i[s] red purple (5 RP 2/2 to 6/2).

#### Galena

The hypogene lead ore mineral in the lead-zinc-silve[r] deposits of the quadrangle is silver-bearing galena. Al[-] though much of it has been weathered to cerussite an[d] other supergene lead minerals, massive aggregates o[f] coarse-grained galena are mined in the highest-grad[e] ore; a little remains exposed in the mine workings, an[d] traces are exposed in prospect pits.

The galena occurs in veins and replacements alon[g] fractured zones in carbonate rocks, as at the Ubehebe[,] Lippincott, and Shirley Ann mines. The largest deposit[s] are in carbonate rocks, but some galena occurs with py[-] rite, chalcopyrite, and a little tetrahedrite in quartz vein[s] that cut quartz-monzonite, as at localities in the Nelso[n] Range, including the Cerrusite mine, and southwest o[f] Ubehebe Peak. At least some of the galena is interstitia[l] around euhedral quartz, but some replaces quartz, espe[-] cially in quartzite associated with dolomite marble[.] Galena also replaces vein calcite.

After supergene alteration of massive galena, speck[s] of galena remain in some of the cerussite formed fro[m] the principal part of galena, giving the massive cerussit[e] a dark, nearly opaque, submetallic appearance. Polishe[d] sections show that the specks of galena decrease in siz[e] and number in the cerussite outward from the unaltere[d] galena, and that much less commonly the specks ar[e] concentrated in thin colloform bands of cerussite an[d] anglesite. A little galena in polished sections from th[e] Shirley Ann mine, where it is associated with chalcopy[-] rite, is replaced by covellite and combinations of chalc[o-] cite and covellite. Less intimately associated supergen[e] products of galena include wulfenite and arsenian va[-] nadinite.

#### Garnet Group

Massive to euhedral garnet of various colors, is a con[-] stituent of tactite at many places along the contact o[f] carbonate rock with massive intrusive rock. The color[s] range from very pale orange through many browns t[o] practically black (brown or yellowish in thin section[)] and from very pale yellowish green to grayish oliv[e] green. A little of the practically black and brownish[-] black garnet, melanite, occurs in syenite; but either a[s] an accessory or a varietal mineral, melanite is locall[y] the only mafic constituent of some of the syenite.

Euhedral parts of garnet lie against calcite, whic[h] readily dissolves during weathering and leaves cryst[al] faces of garnet lining the cavities. Considerable euhedr[al] epidote and a little subhedral heulandite and stilbite ac[-] company garnet in some of these cavities. Garnet cryst[al] faces at some localities show zoning by differences i[n] color. Some garnet at the crest of the Nelson Range ([see] fig. 2), 1.6 miles N. 36° E. of the Cerro Gordo road junc[-] tion in San Lucas Canyon, is grayish olive green (5 G[Y] 3/2) at the interfacial angles and grades abruptly t[o] grayish yellow green (5 GY 7/2) or nearly colorless i[n] the central part of the faces. Internal zoning is bett[er] shown in very coarse grained subhedral garnet b[y] changes in color from grayish brown (5 YR 3/2) t[o] very pale orange (10 YR 8/2). The specific gravity o[f] a sample consisting largely of the darker part, as dete[r-] mined by means of a pycnometer at room temperatur[e] is 4.18. The index of refraction is about 1.77, and sma[ll] agments fuse into dark globules, that are not attracted ' a strong magnet. Some of this garnet is sharply re-aced by epidote along favored zones, making light-ive (10 Y 5/4) bands through the brown, and some irregularly replaced by epidote and calcite. Other rk-brown garnet, considered to be andradite because fuses to magnetic dark glass and has a refractive dex about 1.861, in thin section shows birefringent inned zones. Jewell J. Glass of the U. S. Geological irvey, determined some properties of a black garnet m local syenite in mixed rock at the intrusive con-ct with marble south of Ubehebe Peak. Miss Glass re-rts (written communication, 1950) that it is isotropic, e index of refraction is 1.86, a qualitative test showed me titanium, and a quantitative test gave 36 percent $O_2$; thus, "Physical, chemical, and optical properties int conclusively to melanite garnet."

#### Gold

A very little native gold is visible in a specimen of spery material from the main vein in the Lost Burro ine. The brown jasper cuts across fractured, massive in quartz and in turn is cut by minute stringers of iartz. The massive quartz contains some pyrite and alcopyrite. Other parts of the vein, extensively mined r the gold, contain much coarse-grained calcite and rthy limonite. Although the deposit in the Lost Burro ine is the only one mined solely for gold, the lead-zinc-lver deposits have yielded a little gold. None of the eological Survey's 56 samples from three lead-zinc-lver and two copper properties contain more than 0.07 nce of gold per ton. The sampling was not systematic it probably includes the most favorable exposures of ese deposits.

#### Hematite

Some earthy hematite is associated with limonite in ipergene mineral deposits. Massive hematite is asso-ated with magnetite in a vein between 1 and 2 feet ick in marble southeast of the Lippincott area. Spec-ar hematite occurs in quartz veins that are in quartz-onzonite southwest of Ubehebe Peak and in an aplitic ne in quartz-monzonite in the southeastern corner of e quadrangle. Stringers of specular hematite occur in me albitized quartz-monzonite, such as at the northern ot of the Nelson Range, in Saline Valley.

#### Hemimorphite

Euhedral crystals of hemimorphite cluster in or line nall cavities at many places in the Ubehebe and Lippin-tt mines, but some aggregates that fill cavities consist anhedral grains. The euhedral crystals are colorless, ng, thin, and flat; they are seen to be well striated, hen magnified, and they have a highly glassy luster. ome of the best crystals, which are about 5 mm long and mm wide, line cavities near the foot of the raise to the uth stope in the Ubehebe mine; specimens are on the ine dump. The hemimorphite was identified by optical roperties, such as the optic orientation, the positive oderate axial angle, and the refractive indices, and by e blue reaction with cobalt nitrate solution when heated ıder blowpipe.

The hemimorphite at some places is associated only ith a little hydrozincite, but at most places the hemi-orphite is associated with combinations of supergene lead minerals (cerussite and wulfenite), limonitic masses, quartz, chalcedony, and aragonite. Hemimorphite crystals formed on some hydrozincite, cerussite, chalcedony, drusy quartz, and earthy limonite, which it also encloses, but quartz, wulfenite, and aragonite continued to crystallize later.

#### Heulandite

See zeolite group.

#### Huebnerite

See ferberite.

#### Hydrozincite

A little hydrozincite makes shells under hemimorphite linings and fillings of small cavities in the Ubehebe mine. Specimens were found on the mine dump. Traces of hydrozincite occur also in the Lippincott mine. The hydrozincite from the Ubehebe mine is white and much of it is in minute elongate grains alined across colloform or concentric layers. It brilliantly fluoresces bluish white (5 B 9/1) in ultraviolet light, effervesces in dilute hydrochloric acid, and with cobalt nitrate solution turns green when heated with a blowpipe. As these are properties also of smithsonite, the hydrozincite is distinguished by its less extreme indices of refraction, which are considerably lower in cleavage fragments, and the consequently weaker birefringence. Fluorescence of minute grains suggests that hydrozincite is also disseminated through the hard, light-brown matrix around the aggregates of hydrozincite.

#### Iddingsite

Iddingsite forms rims around olivine or completely replaces it commonly in olivine-basalt of the quadrangle. The iddingsite makes generally inconspicuous brown spots in a hand specimen, but in thin section it stands out in color, which commonly is moderate reddish brown (10 R 4/6) or light brown (5 YR 5/6), and which commonly is zoned. The iddingsite has strong birefringence, somewhat masked by the color, and it has refractive indices lower than that of the olivine it replaces.

#### Idocrase

Coarse-grained idocrase is associated with varied combinations of garnet (most persistently), quartz, calcite, epidote, and feldspar in some of the calc-silicate zones near contacts with quartz-monzonite. A locality accessible from the road between Saline and Racetrack valleys is in the first gully east of the Bonanza mine. Masses of idocrase here are weakly radioactive on a Geiger counter. A somewhat less accessible occurrence is in a prominent tactite zone west of the Spanish mine in the Lippincott area (see pl. 2). The idocrase, in anhedral and subhedral elongate grains, some more than an inch long, is commonly light olive in color but ranges from moderate olive brown (5 Y 4/4) to grayish yellow green (5 GY 7/2). The color, combined with elongate grains showing cleavage and a tendency to develop faces of tetragonal prisms, readily distinguishes the idocrase from the associated minerals. The idocrase has been verified by optical properties in fragments and thin section.

#### Ilmenite(?)

Some of the opaque grains in the plutonic rocks may be ilmenite, as sphene is a common associatied mineral. But alteration products of ilmenite, such as leucoxene, are not conspicuous, and most of the black opaque grains that have been tested are highly magnetic. What may be ilmenite associated with leucoxene appears in a thin section of hornfels derived from Rest Spring shale in San Lucas Canyon.

#### Jarosite

Small jarosite crystals protrude into cavities in a solid aggregate of fine-grained jarosite in the east shaft of the Lost Burro mine (see pl. 3). Yellowish earthy material that occurs widely in the mineral deposits perhaps includes some jarosite as well as limonite. The jarosite crystals from the Lost Burro mine are small fractions of a millimeter in diameter, light brown, and vitreous in luster on the faces, whereas fracture surfaces are resinous. The color of the solid aggregate grades from light brown to grayish brown. The streak from the visibly crystalline part is pale to dark yellowish orange (10 YR 8/6 to 6/6). The material reacts as a sulfate, produces no sublimate on charcoal, and in a closed tube yields water that is acidic. A fragment that shows a good uniaxial negative interference figure has nO greater than 1.72. This jarosite occurs in a minor quartz vein, containing limonite, hematite, clay, and opal.

#### Jasper

See chalcedony.

#### Leucoxene

See ilmenite.

#### Limonite

The wide distribution of limonite in the quadrangle has been emphasized. The supergene mineral deposits contain limonite in earthy mixtures, compact masses grading into brown jasper, residual boxworks, and pseudomorphs after pyrite.

#### Magnesite

Some white porcelaneous tough material, having a conchoidal fracture and a hardness between 5 and 6, is extremely fine grained magnesite. Although it does not effervesce in cold dilute hydrochloric acid, it dissolves with effervescence in hot concentrated acid, leaving no residue of other minerals or silica gel; therefore the abnormal hardness, which was determined on fresh apatite and orthoclase, is apparently not caused by intermixed siliceous material. The solution reacts strongly for magnesium but not for calcium. Fragments under a microscope consist of aggregates of very fine grains that are strongly birefringent. A differential thermal analysis of a finely crushed sample gives a curve that is characteristic for magnesite (Kulp, Kent, and Kerr, 1951, p. 656). The initial decomposition temperature is 540° C and the endothermic peak temperature is 680° C for the single peak, which has great amplitude.

The magnesite fills small fissures in coarse-grained dolomite marble near a contact with quartz-monzonite in the central part of the Sally Ann area. The carbonate mineral in a sample of the adjacent marble is clearly dolomite rather than magnesite. Three-fourths of a mile beyond the eastern border of the quadrangle, similar magnesite occurs in marble near an intrusive contact at a place about 1,500 feet south of the Goldbelt road in the divide between Ulida and Sand flats. This porcelaneous magnesite is somewhat siliceous, particularly in the yellowish-gray part that completely heals a breccia of the white magnesite.

#### Magnetite

Magnetite is an accessory mineral in most of the igneous rocks and in much of the silicated part of the contact-metamorphic rocks. It is abundant in the olivine basalt. The coarsest-grained magnetite seen in the plutonic rocks occurs as grains commonly 5 mm in diameter in syenitic pegmatite and other somewhat albitized syenitic facies of quartz-monzonite relatively near contacts. It is associated with some epidote and tourmaline, and traces of molybdenite or of scheelite, about 0.8 mile N. 30° E. of Big Dodd Spring. Some of the magnetite in plutonic rocks at other places in the Dodd Springs area has excellent parting, making it superficially resemble wolframite. The greatest concentration of magnetite seen in thin sections of igneous rocks is 6 percent of the volume of banded gabbro at the contact with marble west of Hidden Valley. Gabbro southeast of the Dodd Springs contains 2 or 3 percent magnetite. Tactite contains the coarsest magnetite. Near the Blue Jay mine (see fig. 2) magnetite grains in tactite are more than 10 mm in diameter. Anhedral magnetite here is intergrown with epidote, garnet, calcite, and quartz, and druses of euhedral magnetite crystals about a millimeter in diameter cover some euhedral quartz. More massive medium-grained magnetite occurs with hematite in a vein cutting marble southeast of the Lippincott area.

#### Malachite

Malachite, although less abundant than chrysocolla in outcrops, occurs to some extent in many widely scattered copper deposits of the quadrangle. It is fine grained and does not make sizable masses in the exposures. Some malachite (collected by E. M. MacKevett) from the Copper Bell mine has a drusy covering of clear quartz crystals.

#### Molybdenite

Traces of molybdenite were seen at one locality (no. 5, fig. 2), in a syenitic pegmatite zone 0.8 mile N. 30° E. of Big Dodd Spring. Attention was attracted to the molybdenite grains, which are soft, black, metallic flakes as much as 7 mm in diameter, by fluorescence of intimately associated powellite. Considerable magnetite is contained in the host rock, which consists essentially of orthoclase replaced variedly by albite and by epidote in veinlets and interstitial grains. Molybdenite, although not seen, probably was the source of molybdenum in wulfenite of the supergene lead deposits.

#### Muscovite

The little muscovite that has been seen appears to be a product of alteration in plutonic rocks and a constituent of some fine-grained contact-metamorphic rocks. Muscovite occurs, for example, in partly radial clusters like some closely associated chlorite, and in some grains isolated in albite of albitized quartz-bearing monzonite $1\frac{1}{4}$ miles S. 20° W. of Big Dodd Spring. The range in size decreases to the shred size characteristic of sericite. It is associated with black tourmaline, quartz, and albite in clots in aplitic zones in quartz-monzonite at the southern border of the quadrangle. Sericite is a common alteration product of the granitic wall rock in the Cerrusite mine, and of chiastolite in hornfels. Muscovite in metamorphosed shaly siltstone at contacts with quartz-monzonite accompanies quartz, some magnetite, and accessory minerals.

### Olivine

All the volcanic flows thus far examined consist of ivine-basalt. In general, olivine is clearly visible, and me phenocrysts are as much as 13 mm long. The glassy ains are mostly olive but range from dark greenish ay (5 GY 4/1) in some of the largest to nearly color-ss. Much of the olivine is partly altered to iddingsite. livine basalt covers large areas in the southern part the quadrangle and remains in small patches north-ıst of Saline Valley.

### Opal

Some common opal occurs in the vein exposed by the ıst shaft of the Lost Burro mine. A massive part of ıe opal is grayish orange (10 YR 7/4), variegated om moderate brown (5 YR 4/4) to white, and a ongy part is white. The index of refraction of the ongy opal, about 1.46, is slightly higher than that the solid opal, about 1.44. Some of the opal has ystallized to chalcedony. The opal is associated in the in with quartz, jarosite, iron oxides, and clay. Some the clay seems to be dispersed through opal.

### Phlogopite

Phlogopite is abundant in some silicated dolomite mar-le near intrusive contacts. Most of it is greenish but a ttle is tinged brown. Cleavage flakes give a negative, ractically uniaxial interference figure displaying mod-ately strong birefringence and have refractive indices nY and nZ) that range from slightly greater than 566 to slightly less than 1.596. The coarsest phlogopite een, making thin books as much as 1½ inches in diame-r, occurs in mixed rock that probably represents a rge sedimentary inclusion or septum between porphy-tic granite and the main quartz-monzonite a few undred feet west of Ubehebe Peak. Phlogopite in a ecimen collected here by J. F. Robertson ranges in ze from the large flakes to microscopic size and in olor from dusky yellowish green to pale yellowish green 10 GY 3/2 to 7/2). It is closely associated with actino-te, calcite, orthoclase, and quartz, and it is less closely ssociated with albite and epidote. More accessible lo-alities are near the Bonanza mine and in the Sally nn area. Spinel may occur more persistently with hlogopite than was recognized during field work. n hills near Ulida Flat, about half a mile beyond ıe quadrangle's eastern border, masses of moderately oarse-grained phlogopite and calcite contain clusters of mall octahedrons of spinel.

### Powellite

Traces of powellite were found by its golden-yellow uorescence in ultraviolet light. The powellite is an lteration product of molybdenite in a syenitic pegma-ite zone 0.8 mile N. 30° E. of Big Dodd Spring. (No. 5, g. 2.) It makes white pulverulent rims around the ıolybdenite and coatings along the cleavage in the ıolybdenite. Traces of scheelite and considerable mag-etite occur in the same rock. About 1,500 feet northeast f this locality, fluorescent specks of powellite are scat-ered through a 3-inch tourmaline-bearing syenite peg-ıatite, which contains magnetite, and which is albitized, ericitized, and epidotized. The pegmatite zones are in uartz-monzonite near a contact with marble.

### Prehnite

White prehnite in anhedral crystals commonly 2 millimeters long is intergrown with diopside, albite, a little melanite, epidote, and sphene in mixed rock at a contaminated border of quartz-monzonite (No. 6, fig. 2) in the Nelson Range. The prehnite-bearing rock is only a few hundred feet from similar rock that contains heulandite and stilbite. The prehnite fuses with intumescence into bubbly, white glass, but cleavage fragments show that the indices of refraction are higher than in zeolites: nX is about 1.611 and nY is about 1.624. The moderate 2V is positive. In a thin section the cleavage traces are parallel to the fast ray, in contrast to the orientation of the cleavage in the associated diopside, and the extinction progresses across the grains that are somewhat curved. The interference colors are normal and the maximum is middle second order.

### Pyrite

Pyrite is widely distributed in a variety of occurrences and mineral associations. Most of the pyrite in the exposed mineral deposits, however, has oxidized to limonite and some hematite. Among the sedimentary rocks, pyrite is a constituent of septarian cores in some of the discoidal concretions in the Rest Spring shale.

### Pyroxene Group

Pyroxene occurs to some extent in nearly every kind of igneous rock recognized in the quadrangle and is plentiful in several kinds of calc-silicate rocks in contact-metamorphic zones. Despite the varied occurrence, pyroxene is at most an accessory mineral in the greatest volume of plutonic rock, which is quartz-monzonite, and it is accessory also in some of the pegmatite, granite, syenite, and syenogabbro. Pyroxene is a varietal mineral in the syenodiorite, diorite, lamprophyre, and some of the monzonite, and an essential mineral in gabbro and olivine-basalt; of these only olivine-basalt is areally extensive.

*Augite* constitutes as much as 26 percent of the volume of syenodiorite and 21 percent of gabbro, but commonly, about 15 percent of each. In small masses of lamprophyric rock in gabbro east of Big Dodd Spring, and of pyroxenite at a contact with marble west of Hidden Valley, augite makes up more than two-thirds of the volume. In the few samples of quartz-monzonite that contain augite, among 34 micrometrically analyzed, augite does not exceed 4 percent.

*Aegirine-augite* in green rims around augite occurs sparingly in some coarse-grained intrusive rocks near contacts with marble. A few thin sections show accessory quantities in a leucocratic, quartz-bearing microperthite rock (nordmarkite) at the eastern boundary of the Sally Ann pluton of quartz-monzonite in contact with dolomite marble, in a leucocratic granite at the western edge of the same quartz-monzonite mass in contact with a siliceous part of the marble sequence, and locally a much greater quantity in syenodiorite at the northwestern part in contact with dolomite marble.

The only observed occurrence of aegirine-augite as an unzoned pyroxene is in minette, which makes dikes through dolomite in the Ubehebe mine area, near a syenitic stock. The aegirine-augite constitutes about 14 percent of the volume of the minette, in which it is associated with 45 percent biotite, 32 percent microcline and orthoclase, 4 percent calcite, and 5 percent total of sphene, apatite, magnetite, and epidote. The aegirine-augite is in slender, subhedral grains, which mostly are 1 mm or less long, although some are as much as 1.5 mm long and are intergrown with biotite and calcite. Some is replaced by epidote. The cleavage and the outlines of some grains are typical of pyroxene. The pleochroism is moderate yellowish green (10 GY 6/4) for X, grayish yellow green (5 GY 7/2) for Y, and moderate greenish yellow (10 Y 7/4) for Z. It is optically negative and rather strongly birefringent. The optic axial angle and the angle of extinction were measured on a universal stage by C. D. Rinehart, U. S. Geological Survey. The average $2V_z$ for 7 grains is 97°, ranging from 94° to 101°, and the average angle between c and Z for 6 grains is 81°, ranging from 78° to 83°. Values for the optic angle and extinction, particularly the averages, correspond to the interrelationship expressed by Larsen and Jenks' curves (1942, p. 48), according to which the average of the sample of the Ubehebe aegirine-augite contains 17 percent $Fe_2O_3$, or if all the $Fe_2O_3$ forms acmite, nearly 50 percent acmite.

*Diopside* occurs in contact-metamorphic rocks of many different textures and of moderately varied mineral compositions. Most of the coarser-grained diopside is greenish gray (5 G 6/1), which makes a lighter aggregate where fine grained and intergrown with feldspar, but some of the coarsest-grained diopside is nearly white, and the brightest colored is moderate yellowish green (10 GY 6/4). The observed range in grain size is from microscopic to about 2 inches long. Very little of it weathers as well-shaped crystals, although some examples of moderately well developed ones as much as 1 inch long are surrounded by a zone of tremolite in metamorphosed chert nodules, about a mile east-southeast of the Lippincott area.

Conspicuous diopside occurs with different combinations of garnet, alkalic feldspar, and calcite in coarse-grained calc-silicate rock near contacts, but perhaps the greatest volume is in the fine-grained, very light colored rock metamorphosed from siliceous limestone at greater distances from exposed plutonic rock. A typical specimen of the great mass of this rock that is exposed in San Lucas Canyon is light greenish gray (5 GY 8/1) and consists of about 50 percent plagioclase, 30 percent diopside, 15 percent wollastonite, and 5 percent accessory minerals. About 5 miles southeast in the same range, coarser-grained diopside, which is greenish gray (5 G 6/1), is a major constituent of mixed rock in a contaminated border of quartz-monzonite, in which it is associated with prehnite and albite and much smaller quantities of melanite, epidote, and sphene. Nearby in the same mixed zone, diopside is associated with heulandite, epidote, alkalic feldspar, coarse-grained apatite, and sphene. The coarsest diopside, forming interlocking anhedral grains commonly 2 inches long, occurs in an outcrop roughly 70 feet long and 5 feet wide in contact-metamorphic rock in the Bonanza mine area. A small part is somewhat sericitized. Nearby calc-silicate rock in marble consists of coarse-grained garnet intergrown with idocrase; pink manganian zoisite in sericite with some garnet and sphene; phlogopite; or wollastonite containing some disseminated chalcopyrite. The color of much of this diopside is yellowish gray (5 Y 8/1), pinkish gray (5 YR 8/1), or somewhat darker from iron oxide stain; but some is completely stained green from supergene copper. The diopside has conspicuous basal parting as well as typical pyroxene cleavage, like the nearly colorless subhedral diopside of some metamorphosed chert nodules. The optic characteristics and orientation in cleavage fragments are typical of pyroxene and nY is slightly less than 1.68, which is characteristic of diopside. The brightest green diopside unstained by supergene copper at a locality about 1½ miles S. 65° W. of the Lost Burro mine, likewise has nY about 1.67; all indices of refraction in fragments are higher than 1.665 and lower than 1.702.

## Quartz

Quartz occurs to some extent in every kind of metalliferous mineral deposit and in many kinds of rock represented in the quadrangle. Despite the wide distribution, quartz is a subordinate rock constituent except in the relatively minor quantities of quartzite, sandstone and siltstone in Paleozoic formations, and some parts of the Cenozoic sediments. In 34 micrometric analyses of representative specimens of quartz-monzonite, which is by far the most voluminous plutonic rock in the quadrangle, the proportion of quartz ranges from 7 percent to 27 percent (only one contains more than 23 percent quartz) and averages about 15 percent. Some pegmatitic masses are largely quartz, as are the few, sporadically metallized veins in the plutonic rocks. Quartz in some of the small veins contains abundant tourmaline, specular hematite, or barite, and in others, traces of galena, tetrahedrite, including mercurian tetrahedrite, chalcopyrite and pyrite. The largest veins, in plutonic rocks, have contained gold ore in the Lost Burro mine, copper ore in the Copper Queen-Lucky Boy mine, and lead ore in the Cerrusite mine. The gangue in other mines also includes quartz. It formed both early and late; some druses of quartz crystals coat limonite, malachite, and wulfenite.

## Rutile(?)

Acicular crystals in andalusite hornfels in San Lucas Canyon probably are rutile. The hornfels is metamorphosed Rest Spring shale.

## Scapolite

Coarse-grained scapolite occurs on either side of some contacts between quartz-monzonite and calc-silicate rock. Euhedral and subhedral scapolite crystals as much as an inch long, partly stained green with supergene copper are on the calc-silicate side of the contact with quartz-monzonite on the Shamrock claim, south of Ulida Flat. Coarse-grained, radial, practically white scapolite, intergrown with actinolite and replaced by epidote lies within quartz-monzonite near the contact about 0.7 mile S. 70° W. of the Shamrock locality. Coarser grained scapolite in larger aggregates at the contact about 1½ miles north of the Lippincott mine has inclusions of actinolite, calcite, and a little coarse apatite. Similarly coarse grained aggregates of scapolite in contact rock about half a mile northwest of the Cerrusite mine, in the Nelson Range contain some pyroxene, actinolite, and sphene. Much finer grained scapolite in grains commonly 1 mm in diameter in the foothills west of Ubehebe Peak constitutes about 14 percent of a contact rock that contains 7[illegible] ercent pyroxene, 4 percent plagioclase, and 7 percent cessory alkalic feldspar, sphene, apatite, chlorite, serite, and opaque minerals. Refractive indices of three idely spaced samples suggest that the scapolite in genal falls within the limits of dipyre, a somewhat sodic ember of the scapolite group. The scapolite north of ie Lippincott mine has refractive indices of nO about 56 and nE about 1.55, placing it in dipyre near the undary with the sodic end member, mariolite; a specien from the foothills west of Ubehebe Peak also is ipyre; and from the Shamrock claim the scapolite is mewhat more calcic, for the indices of nO about 1.57 id nE about 1.55 place it at the dipyre-missonite undary.

### Scheelite

The little scheelite that has been found in the quadingle is described, along with its mineral associations, sewhere in this report.

### Sericite

See muscovite.

### Serpentine Group

Dolomites near intrusive contacts at many places conin small masses of *antigorite*. The color, luster, and rdness are the most distinctive properties of the antigrite in outcrops. The color grades from grayish olive 10 Y 4/2) to pale greenish yellow (10 Y 8/2), but most mmonly is moderate greenish yellow (10 Y 7/4). The itigorite is translucent on thin edges and its luster is reasy or waxy. Much of the antigorite has minute veints of silky chrysotile.

In thin section the antigorite forms a mosaic of weakly irefringent grains cut by veinlets of chrysotile. Some is itergrown with calcite and diopside. Although some ggregates are pseudomorphous after 4- and 8-sided uhedral grains that may have been forsterite (a comionly intermediary mineral in the metamorphism of olomite to antigorite), no unaltered forsterite has been een in the thin sections. Some unaltered euhedral diopide remains with some of the antigorite and calcite, such s in the Lippincott area. A little magnetite occurs with ome of the antigorite; conversely, a little antigorite in ome places, such as the Sally Ann area, occurs in tactite iade up of abundant magnetite and garnet.

The *chrysotile* is silky, pale greenish yellow to modrate greenish yellow (10 Y 8/2 to 7/4). Microveinlets f chrysotile are visible in thin sections of antigorite, vhere in samples they are scarcely visible to the unided eye. The longest fibers found within the quadangle are only about 0.1 inch long. Veinlets of them ut antigorite in tactite of the Sally Ann copper area. onger fibers, commonly as much as an inch long, occur n the Indian Camp claims at Ulida Flat, just beyond he boundary of the quadrangle (R. F. Johnson, oral ommunication, 1951; Murdoch and Webb, 1952, p. 29). About half a mile southeast of this deposit, chrysotile bers as much as 0.25 inch long occur in antigorite that ontains some limonitized pyrite. Traces of chrysotile ccur in the gangue of some lead deposits, such as in he open cut near the main shaft of the Lippincott mine nd in the incline of the Addison workings.

### Sphalerite

Very little sphalerite was seen in the lead-zinc-silver leposits, but the widespread occurrence of hemimorphite in oxidized ore and the production of zinc seem to indicate that sphalerite has been a common hypogene mineral in these deposits. Fresh sphalerite in stringers, clots, and disseminated grains replaces quartzite in the Inspiration workings of the Lippincott mine. Within a single specimen the sphalerite ranges in grain size from microscopic to about 5 millimeters in diameter and in color from very dark (nearly olive black, 5 Y 2/1) to very light. A little pyrite and less chalcopyrite are disseminated with the finest grained and lightest colored sphalerite.

### Sphene

Sphene is a conspicuous accessory mineral in most of the plutonic rock; it is in all thin sections of the 34 representative samples of quartz-monzonite that were micrometrically analyzed, in quantities as much as 3 percent of the volume. Pale yellowish or brownish euhedral grains several millimeters long are commonly discernible in hand specimens. Unlike accessory apatite and magnetite, sphene has not been seen in thin sections of the most calcic facies of plutonic rock, such as gabbro, syenogabbro, diorite, and some of the syenodiorite. Sphene appears in thin sections of a wide variety of contact-metamorphic rocks and mixed rock, together with such combinations of minerals as scapolite, diopside, actinolite, and calcite; alkalic feldspar, epidote, diopside, heulandite, and apatite; manganian zoisite and sericite; fine-grained diopside and plagioclase; and plagioclase, epidote, apatite, and magnetite in quartzite.

### Spinel

Although no spinel has been found in specimens from the Ubehebe Peak quadrangle, it may be present in some of the many occurrences of phlogopite-calcite rock that is similar to spinel-bearing rock a few thousand feet east of the quadrangle. This locality, where spinel was collected in 1946, is probably the one on record as at the south end of Butte Valley, Ubehebe(?) mining district (Murdoch, 1949, p. 532). Butte Valley is an old name for Hidden Valley, which includes Ulida Flat. East of Ulida Flat, on the hillside south of the Ubehebe talc mine, well-formed octahedrons of black spinel are commonly from 1 to 2 mm in the longest dimension, forming clusters in coarse-grained aggregates of calcite and green phlogopite. Fragments of the spinel in transmitted light are clear green. The refractive index is between 1.745 and 1.750.

### Stilbite

See zeolite group.

### Talc

See talc in section on mineral deposits.

### Tetrahedrite

Traces of mercurian tetrahedrite (schwazite) occur with galena in a thin quartz vein in the western part of the Ubehebe Peak mass of quartz-monzonite. An incipiently weathered specimen has some green copper stain around the tetrahedrite but no fine-grained cinnabar, which in other districts is produced by more thorough oxidation of mercurian tetrahedrite. Heating clean fragments of the unweathered tetrahedrite produces a dark shadow on a willemite screen under ultraviolet light, showing the presence of mercury. Traces of a red mercury-bearing mineral in some of the supergene lead ore in the Ubehebe mine possibly came from the weathering of mercurian tetrahedrite.

### Thulite

See zoisite.

### Tourmaline

Black tourmaline, although not abundant, is widely distributed in varied occurrences. Moderately coarse black tourmaline is in clots associated with quartz, albite, fine-grained muscovite, or epidote, in pegmatitic and aplitic facies of the quartz-monzonite. Some occurs in a thin dike of syenite northeast of Big Dodd Spring (about 1,000 feet northeast of locality 6, fig. 2). Clots of tourmaline and quartz are well developed in a broad aplitic zone about 1½ miles southwest of the pass between Panamint and Saline Valleys (no. 8, fig. 2). Veins of tourmaline, with or without quartz, calcite, or barite, occur in contact-metamorphic rock and quartz-monzonite near contacts. A lode-like zone of tourmaline veinlets in quartz-monzonite, 1.2 miles east-northeast of Big Dodd Spring, contains some pyrite, chalcopyrite, and their oxidation products. Vein tourmaline in the Lippincott area makes dark gray (N 3) very fine grained aggregates. In thin section this tourmaline is pleochroic from nearly colorless (verging on grayish yellow green, 5 GY 7/2) to grayish green (10 G 4/2). Tourmaline constitutes a small part of some hornfelsic rock made of quartz, sericite, biotite, and much carbonaceous material.

### Ulexite

Chalky white ulexite impregnates silt and fine-grained sand from a former lake along the eastern side of the flats in Saline Valley within the western boundary of the Ubehebe Peak quadrangle. The fine-grained borate mineral in a typical sample of the lake sediment was identified as ulexite by R. D. Allen (written communication, 1953). The ulexite is associated with no other saline in the material examined by him. The sample of lake sediment contains 1.45 percent $B_2O_3$ according to an analysis by Henry Kramer (written communication, 1953).

### Vanadinite

Crusts and clusters of arsenian vanadinite crystals, few more than a millimeter in length, line cavities in limonite boxwork and residual siliceous material. The arsenian vanadinite is most abundant in the upper part of the north stopes in the Ubehebe mine, but it occurs also in the lower part of the north stopes and in the south stope. Most of the larger grains are barrel-shaped, from a curved hexagonal prism combined with a pinacoid, but some from the south stope lack the pinacoid and look like miniature, longitudinally ribbed grains of wheat. The color of the arsenian vanadinite in a single hand specimen commonly ranges from grayish brown (5 YR 3/2) in the larger crystals to dark yellowish orange (10 YR 6/6) in the smaller ones, but some of the smallest are much paler, and some of the wheat-shaped grains are greenish gray (5 GY 6/1). The specific gravity, as determined by pycnometer, is 6.7. The qualitative determination of arsenian vanadinite was verified by Henry Kramer's quantitative partial analysis of a typical sample that contains 10.84 percent $V_2O_5$ and 2.91 percent $As_2O_5$ (Kramer, written communic tion, 1953). The arsenian vanadinite is commonly ass ciated with wulfenite, and both are somewhat radi active.

### Wolframite Series

See ferberite.

### Wollastonite

Wollastonite, which occurs widely in the calc-silica rock, forms anhedral grains ranging in size from micr scopic, as in the wollastonite-diopside-plagioclase ro of San Lucas Canyon, to as much as 4 inches long somewhat bladed aggregates of wollastonite near t Bonanza mine. The wollastonite generally is near white, but the coarsest wollastonite, which contains d seminated grains of chalcopyrite, ranges from lig brownish gray (5 YR 6/1) to yellowish gray (5 Y 8/1 The wollastonite was identified by its characteristic o tical properties, including the orientation of the opt axial plane, which is about 4° from normal to the zo of cleavage, and the nX of about 1.62. C. D. Rineha (written communication, 1952) took two readings of t 2V from the same grain on a universal stage and g 35° and 36°. Wollastonite at the quartz-monzonite co tact of a 100-foot zone of calc-silicate rock (No. 3, fig. 1.6 miles N. 36° E. of the Cerro Gordo road junction San Lucas Canyon, is closely associated with gree zoned garnet, calcite, epidote, quartz, chalcedony, ar stilbite. Southwest in the same range, at a contact abo 2,000 feet N. 80° E. of the end of the road north of t Cerrusite mine, white wollastonite is intergrown wi moderately coarse grained grayish-green diopside ar forms some coarser grained aggregates of pure wolla tonite in marble.

### Wulfenite

Yellowish-orange wulfenite makes conspicuous, ope crystal meshes on limonite in the upper part of the nor stopes in the Ubehebe mine, where it occurs also wi druses of hemimorphite and near drusy crusts of arse ian vanadinite. Wulfenite occurs widely in much small proportions with cerussite in other stopes of the mi and in the Lippincott mine. Almost all the wulfenite in euhedral crystals; the larger crystals are thinly tab lar, commonly as much as 2 mm in diameter and a sma fraction of a millimeter thick (the largest crystal see is about 10 mm in diameter and half a millimeter thick and the smaller are nearly acicular, forming cluste and coatings. The identification of the wulfenite w verified by its optical properties and by blowpipe tes for lead and molybdenum. Some wulfenite crystallize on cerussite and at the same time as hemimorphite, a though in general the wulfenite continued forming aft the hemimorphite. Quartz covers some tabular wulfenit

Wulfenite marks places of greater radioactivity an samples rich in wulfenite contain traces of uranium. Th most uranium found is in a sample consisting almost e tirely of wulfenite, which according to a chemic analysis by J. Meadows (written communication, 1951 contains 0.050 percent uranium.

### Zeolite Group

*Heulandite* has been found at two places 1,000 fe apart on the crest of the Nelson Range, about 2,000 fe north of the Cerrusite mine. It is in contaminated borde cies of quartz-monzonite. At the eastern locality, a cop-r prospect called Green Eye (No. 9, fig. 2), it is in otite-augite syendiorite, and at the western locality it in mixed rock containing much alkalic feldspar, epi-te, diopside, melanite, apatite, and sphene. The heu-ndite is associated with stilbite. The pearly white or lorless heulandite grains are mostly anhedral or sub-dral but some euhedral crystals as much as 8 mm long ıster in what are now cavities. Cleavage fragments ow a well-centered positive acute-bisectrix figure, with spersion of r clearly less than v, a moderate axial angle, d nX and nY between 1.495 and 1.500. On heating, the ulandite exfoliates and swells before fusing to glass.

*Stilbite* occurs, in addition to its association with ulandite in mixed rock north of the Cerrusite mine, calc-silicate rock at the contact with quartz-monzonite No. 3, fig. 2) 1.6 miles N. 36° E. of the Cerro Gordo ad junction in San Lucas Canyon and in aplite cutting orite 0.6 mile east of Big Dodd Spring. The mineral sociation in the calc-silicate rock is described under llastonite. East of Big Dodd Spring, stilbite in euhe-al and subhedral grains, commonly about 5 mm long d partly in sheaf clusters, is associated with some artz in vuggy parts of an aplite-pegmatite zone. This lbite is grayish orange (10 YR 7/4) in contrast to e yellowish gray and white stilbite at the other lo-lities, where it is generally in radial clusters. Like ulandite, it swells before fusing, and fragments have mewhat similar optical properties, but the stilbite is adily distinguished by the optic orientation of cleavage agments.

### Zoisite

Pink, very fine grained manganian zoisite (thulite) is attered through nearly white silicate rock and con-ntrated in some veinlets in the contact-metamorphic ne a few hundred feet east of the Bonanza workings. also replaces some coarse-grained idocrase and light-own garnet. The brightest colored manganian zoisite moderate pink (5 R 7/4), but most of it is paler, and thin section it is colorless. The optic axial plane is rmal to cleavage traces, the moderate 2V is positive, d the weak birefringence includes an anomalous blue. ne refractive indices are between 1.669 and 1.708. The anganian zoisite is associated with abundant fine-ained muscovite, diopside, and considerable sphene. is may be the source of the thulite in boulders re-rted from the eastern side of Saline Valley near the uthern end (Schaller and Glass, 1942, p. 519; Mur-ch and Webb, 1948, p. 320).

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